

**OPTIMIZATION
OF THE
PAISLEY WATER TREATMENT PLANT
FOR
CONTROL OF TRIHALOMETHANES**

SEPTEMBER 1997



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Report prepared for:

Standards Development Branch
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EXECUTIVE SUMMARY

BACKGROUND

The two main objectives of the study are:

1. Improvement of the water treatment plant performance to meet the new Ontario Drinking Water Objectives (ODWO) THM guideline to achieve a filter effluent turbidity of 0.1 NTU without compromising disinfection and to meet the aluminum operational guideline of 100 µg/L.
2. Sustaining long term performance through skills transfer to plant operating staff and recommendations for plant upgrades where required.

The optimization study was funded by the Ontario Ministry of Environment and Energy (MOEE), and is a cooperative public/private project between the MOEE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities should be capable of producing water that meets the new THM objective, and also be capable of improved particle removal and lower aluminum residuals, without requiring costly upgrades.

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics. Trihalomethanes are suspected of increasing the risk of cancer following long term exposure. The Ontario government has lowered the guideline from a maximum acceptable concentration of 350 µg/L, measured as a single occurrence, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

The associated treatment parameters of turbidity and aluminum residual were also subject of the optimization effort. The ODWO for turbidity is 1 NTU, but current research now indicates that a filter effluent turbidity of 0.1 NTU is needed to provide protection from cryptosporidium. To reduce potential for disease outbreaks, this study will evaluate the feasibility of obtaining a turbidity of 0.1 NTU in the filter effluent. The ODWO operational guideline (not health related) for aluminum in drinking water is 100 µg /L.

The optimization of a water treatment plant consists of evaluating the existing treatment units, conducting laboratory testing to determine the best choice and dosage of the treatment chemicals, and implementing changes to plant operation.

EXISTING CONDITIONS

The Village of Paisley Water Treatment Plant was built in 1976 and treats water from the Teeswater River. It is a conventional 'package plant' consisting of an Infilco solids contact clarifier and two dual media filters. The plant uses alum, activated silica, and chlorine gas in the treatment process. The plant, in addition to other Village facilities, is presently operated by three Village staff.

A summary of data from the 1996 sampling is presented as follows:

	<u>UNITS</u>	<u>RAW WATER</u>	<u>TREATED WATER</u>
Colour:	TCU	17 to 31	1 to 5
Turbidity:	NTU	4 to 6	0.2 to 1
pH:		8.2 to 8.5	7.6 to 8.2
Alkalinity:	mg/L CaCO ₃	195 to 218	195 to 218
Trihalomethanes	µg/L		89 to 189 (note max. 128 µg/L after pre-chlorination discontinued)

Plant flows are generally:

Average day:	568 m ³ /d (0.13 MIGD)
Maximum daily flow:	840 m ³ /d (0.19 MIGD) (Over an 11 hour operating period)
Design capacity:	1,504 m ³ /d (0.33 MIGD)

PERFORMANCE ASSESSMENT

The river supply to the plant is moderate in colour and variable in quality particularly in the spring runoff period. In general, the plant is meeting the MOEE guidelines for turbidity and colour however, the variable range in quality for the treated water indicates more control over the treatment process and reduced flow rates, i.e. a longer operating period, are warranted. In addition, aluminum residuals in the treated water have periodically exceeded the guideline of 100 µg/L.

Temporary adjustments were made to the alum application points that seemed to have a beneficial effect on clarifier effluent quality. Prior to the start of the optimization study the plant staff discontinued the pre-chlorination which reduced the THM formation.

Currently there are deficiencies in the lack of mixing, lack of raw water flow metering and in the performance of the clarifier. The current practice of operating the plant within an 11 hour period is causing flow rates in excess of the process units' rated capacity. The resultant carry over from the clarifier puts a higher load on the filters and contributes to the variable effluent quality. This is an indicator of potential for breakthrough of harmful organisms. A detailed assessment of the disinfection was made using the flow rates for the 11 hour operation. There is inadequate chlorine contact time to ensure the high level of inactivation required for giardia to safeguard public health.

The THM results obtained from on-site testing performed in July and August, 1996 average 124 µg/L at the treatment plant and 112 µg/L in the distribution system. Winter levels will be lower and the running four quarter average may be below the new ODO guideline. Further monitoring over the next year will be done.

The turbidity of the treated water ranges from 0.4 to 0.9 NTU with an average of 0.7 NTU. While this is below the ODO for turbidity of 1 NTU, it indicates less than optimum performance and the variable results indicate a lack of control which was felt to be a result of a lack of on-line monitoring instrumentation and the previously mentioned high hydraulic loading.

RECOMMENDATIONS FOR PLANT SCALE MODIFICATIONS

The following is a summary of recommendations for plant scale modifications required to ensure that the Paisley Water Treatment Plant will be in compliance with the ODFW for THM and aluminum residual, better able to aim for a turbidity in the filter effluent of 0.1 NTU:

- Slow the flow rate through the plant, with the necessary adjustment to treatment chemicals, to achieve improved and more consistent performance from the clarifier and to allow for sufficient chlorine contact time. This may be done by throttling the raw water pump discharge or by adding a variable frequency drive to the pump to provide variable speed operation;
- Install baffles in the clearwell to reduce short circuiting and to increase the contact time for better disinfection;
- Install a magnetic flow meter on the raw water pipe;
- Shift alum addition to a point downstream of the raw water pump and the new flow meter and install an in-line static mixer immediately downstream from alum addition;
- Provide continuous monitoring of settled water pH and alarm to alert operator of process upsets;
- Install in-line turbidimeters on each of the filter effluents.

COST ESTIMATE FOR IMPLEMENTATION

The following table is a summary of capital expenditure involved for the implementation of the recommended up-grades. The figures presented are estimates prepared to give an idea of the price range involved. The capital cost estimate for plant upgrades is \$43,000, if a throttling valve is used to lower the plant flow or, \$48,000, if a variable speed controller is installed to control the low lift pump instead of using a throttling valve.

Capital Cost Estimates

PROPOSED MODIFICATIONS	COST (\$)
Permanent relocation of alum injection point immediately downstream of the low lift pumps with installation of a static mixer and two alum injection pumps (one used as standby)	\$11,000
Throttling valve or variable speed controller for the low lift pump	\$5,000 or \$10,000
Raw water flow meter	\$8,000
Installation of baffles in the clearwell	\$8,000
Installation of turbidimeters and chart recorder	\$8,000
Installation of in-line pH meter	\$3,000
TOTAL (for throttling valve installation)	\$43,000
OR	OR
TOTAL (for variable speed controller installation):	\$48,000

OFF-SITE AND ON SITE TESTING

A preliminary screening study was performed on water collected at the plant and sent to the MOEE Water and Wastewater Optimization Section. This testing indicated both alum, ferric sulfate, and PACL in combination with polymers or activated silica performed well for colour and turbidity removal. The best performance was with alum and activated silica as is in use at the plant. A temporary relocation of the alum feed to the low lift pump discharge was made to get better mixing. This appeared to produce more consistent clarifier performance.

CONCLUSIONS

Elimination of the pre-chlorine feed appears to have reduced the THM formation and while the summer values are still above 100 µg/L, it is expected the average of four quarterly samples will be at or below the new guideline. Further monitoring will be carried out to confirm these results. Calculations indicate however that there is lack of adequate disinfection contact time due to high flow rates and lack of baffling in the clearwell.

It has been difficult to achieve the goal of 0.1 NTU and the 100 µg/L maximum aluminum residual. This is due to the high rate of flow that the plant is operated at and in deficiencies in mixing, flow measurement, and the lack of on-line monitoring. To achieve the high level of performance that will provide the greatest protection against harmful organisms, it is necessary to maintain a smooth flow pattern that is within the hydraulic design of the process units. It is also necessary to have precise control over the addition of the treatment chemicals, have good dispersion of those chemicals and to have a continuous readout and record of the plant performance as measured by the turbidity of the filter effluent. This usually results in the added economic benefit of making the most effective use of the treatment chemicals.

The Paisley raw water source is subject to contamination from human and agricultural discharges and the risk of water borne disease in the river is high. This source requires effective water treatment and a consistent high quality effluent to ensure the public health is protected. While the effluent quality has generally been within the OWDO guidelines, observations of the plant operation indicate inconsistent performance that could lead to a breakthrough of harmful organisms. Recommendations have been made to the Village for modifications that are inexpensive, simple to implement, and would significantly improve performance however, these recommendations have not been carried out. A cooperative effort from the Village is necessary to provide the best possible treated water quality to the Village residents.

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1.0 BACKGROUND

Trihalomethanes (THMs) are by-products created when the chlorine used in the disinfection process reacts with naturally occurring organics (eg. formed by decay of algae and vegetation) in raw water. Surface water containing high organics also often have high colour levels. The most common forms of trihalomethanes created are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.

The formation of THMs is influenced by several factors:

- | | | |
|-------------------------------|--------------------------------|--------------|
| • Free chlorine concentration | - higher Cl ₂ | = higher THM |
| • Organic content | - higher organic concentration | = higher THM |
| • pH | - higher pH | = higher THM |
| • Temperature | - higher temperature | = higher THM |
| • Time | - generally longer time | = higher THM |

Since the formation of trihalomethanes is associated with the presence of organics in the water, small inland lakes and rivers, which may contain more organics than large clear bodies of water have a greater trihalomethane formation potential, especially during periods of high runoff.

The reason for adding chlorine to drinking water is to inactivate bacteria and other microorganisms that can cause numerous illnesses. However, chlorine use leads to the presence of trihalomethanes and this is a cause for concern; studies have found an association between high levels of trihalomethanes in chlorinated drinking water, and slight increases in cancer following long term exposure of more than 35 years.

Chlorine has an advantage over other disinfectants in that it persists many hours or for days and provides protection for the entire water distribution system. The benefit to public health of using chlorine as a disinfectant in drinking water far out-weighs the risk to health associated with the low levels of trihalomethanes created as by-products of chlorination.

In order to decrease the health risk from trihalomethanes, the Canadian and Ontario governments have lowered their respective guideline limits from an “anytime” maximum acceptable concentration of 350 µg/L, to an interim maximum acceptable concentration of 100 µg/L based on a running annual average of four quarterly samples.

Disease outbreaks caused by giardia and cryptosporidium have been reported with increased frequency over the last decade in Canada and the US. These protozoan parasites (especially cryptosporidium) are more difficult to kill than bacteria with disinfectants, and therefore their removal by physical processes is vital. As a result, Health Canada is now examining the need for stricter standards for particle removal in water plants. The current Ontario Drinking Water Objective (ODWO) for turbidity that applies at the water treatment plant is 1 NTU, but current US research and experience now indicate that a filter effluent turbidity of 0.1 NTU is needed to provide protection from cryptosporidium. In the attempt to reduce potential for disease outbreaks, this study attempted to evaluate the feasibility to obtain a turbidity of 0.1 NTU in filter effluent.

Alum (aluminum sulphate) is the most widely used coagulant because it is effective, readily available, and relatively inexpensive. However, under some circumstances, or if not used properly, its use can result in elevated levels of residual aluminum in finished drinking water. An article was recently published on facts about human health and aluminum in drinking water (Environmental Science and Engineering Magazine, January 1997). The following is a summary of the major facts presented in the article.

In recent years, increased attention has been focused on possible adverse effects of aluminum in drinking water on human health. Several epidemiological studies have reported a slightly increased incidence of dementia in communities where drinking water is high in aluminum and these studies have raised concerns among the media and public.

A number of theories on the causes of Alzheimer's disease have been proposed and are currently under investigation. From what we know at this time, the evidence linking aluminum and Alzheimer's disease is far from conclusive, but we also cannot be sure that there is no relationship. Humans are constantly being exposed to aluminum via food, air, and water. Ninety percent (90%) of aluminum intake is from food. In general, exposure to aluminum from drinking water is very low (below 3%) compared with that from food and drugs. At the present time the ODWo for aluminum in drinking water is 100 µg/L, which is an operational not health related guideline.

Owners of water treatment plants and water distribution systems who provide water for consumption have legal responsibilities which are shared by all suppliers of food or drink. Owners and suppliers must take all reasonable measures to ensure the water is fit for consumption or people who may be harmed can successfully sue for damages. In addition, Certificates of Approval issued to permit construction and operation of plants may contain legally binding provisions. If these are not followed and harm results then again claims for damages may be awarded by the courts.

This optimization study is funded by the Ontario Ministry of Environment and Energy (MOEE), and is a cooperative public/private project between the MOEE and RAL Engineering Ltd. By optimizing the performance of their existing facilities, municipalities with a conventional water treatment plant (i.e. coagulation, flocculation, settling, filtration and disinfection) in many cases should be capable of producing water that meets the new THM objective, and also be capable of improved particle removal, without resorting to costly upgrades.

The optimization of a water treatment plant consists of:

- Documentation of existing facility.
- Assessment of the performance of each process unit.
- Verification of the hydraulic loading on each process.
- Laboratory jar testing to determine the best combination of treatment chemicals and the optimum dosages to achieve maximum removal of particulates and dissolved organic material, as well as a minimum level of aluminum residual in the treated water.
- Make required changes to plant operation at full-scale to ensure that changes will minimize the formation of THM, but will not compromise the disinfection requirement.

2.0 OBJECTIVES

The two main objectives of the study are:

1. IMPROVEMENT OF PAISLEY WATER TREATMENT PLANT PERFORMANCE

- Improve plant performance without major capital/equipment expenditures. Specific water quality objectives are listed below in decreasing order of priority:
 - A. To comply with the 100 µg/L ODWO for THMs in treated water as a running annual average of 4 quarterly samples. This objective shall be met while ensuring proper removal and/or inactivation of disease-causing microorganisms such as bacteria and viruses, since this remains the most critical aspect of drinking water treatment.
 - B. To improve particulate removal to reduce or eliminate disease risk from giardia and cryptosporidium. While the ODWO for turbidity is 1.0 NTU, the goal is to achieve 0.1 NTU in the filter effluent.
 - C. To keep aluminum residual at or below 100 µg/L to meet the ODWO.

2. SUSTAINING LONG-TERM PERFORMANCE

- Skills transfer to plant operating staff to enable them to effectively control and adjust processes over the long term in response to raw water quality variations.
- Documentation of plant conditions with recommendations for up-grades and operational modifications.

3.0 DOCUMENTATION OF EXISTING CONDITIONS

The Paisley Water Treatment Plant was put in operation in 1976, and serves a community including the Village of Paisley and Elderslie Township representing a population of 1,200. The rated plant capacity is 1,504 m³/d (0.33 MIGD). The plant is owned and operated by the Village of Paisley.

On inspection in July 1996 the plant was found to conform to the supplied plans. Water is withdrawn from the Teeswater River, pumped by one of two low lift pumps to a mix chamber in a solids contact clarifier (Infilco Accelerator), where alum coagulant and activated silica are added. Overflow from the clarifier flows by gravity to two dual media filters with parallel operation. Sludge blowdown from the clarifier is discharged to the river. Filtrate flows by gravity to a clearwell where chlorine is added. Pre-chlorination was practiced at the plant in the past until December 1995, causing high levels of THMs. Filter backwash water is supplied from the distribution system and is discharged to the river untreated. One of two highlift pumps is used to pump from the clearwell to the distribution system. The distribution system has one pressure zone and a standpipe which "floats" on the system. The standpipe has 2 to 5 days storage capacity depending on seasonal demand. A copy of the Certificate of Approval is presented in Appendix E.

A plant survey was performed during the site visit on July 5, 1996, to prepare a detailed description of existing equipment and conditions of operation. The survey is presented in Appendix A, and a flow schematic of the plant on Figure 3.1.

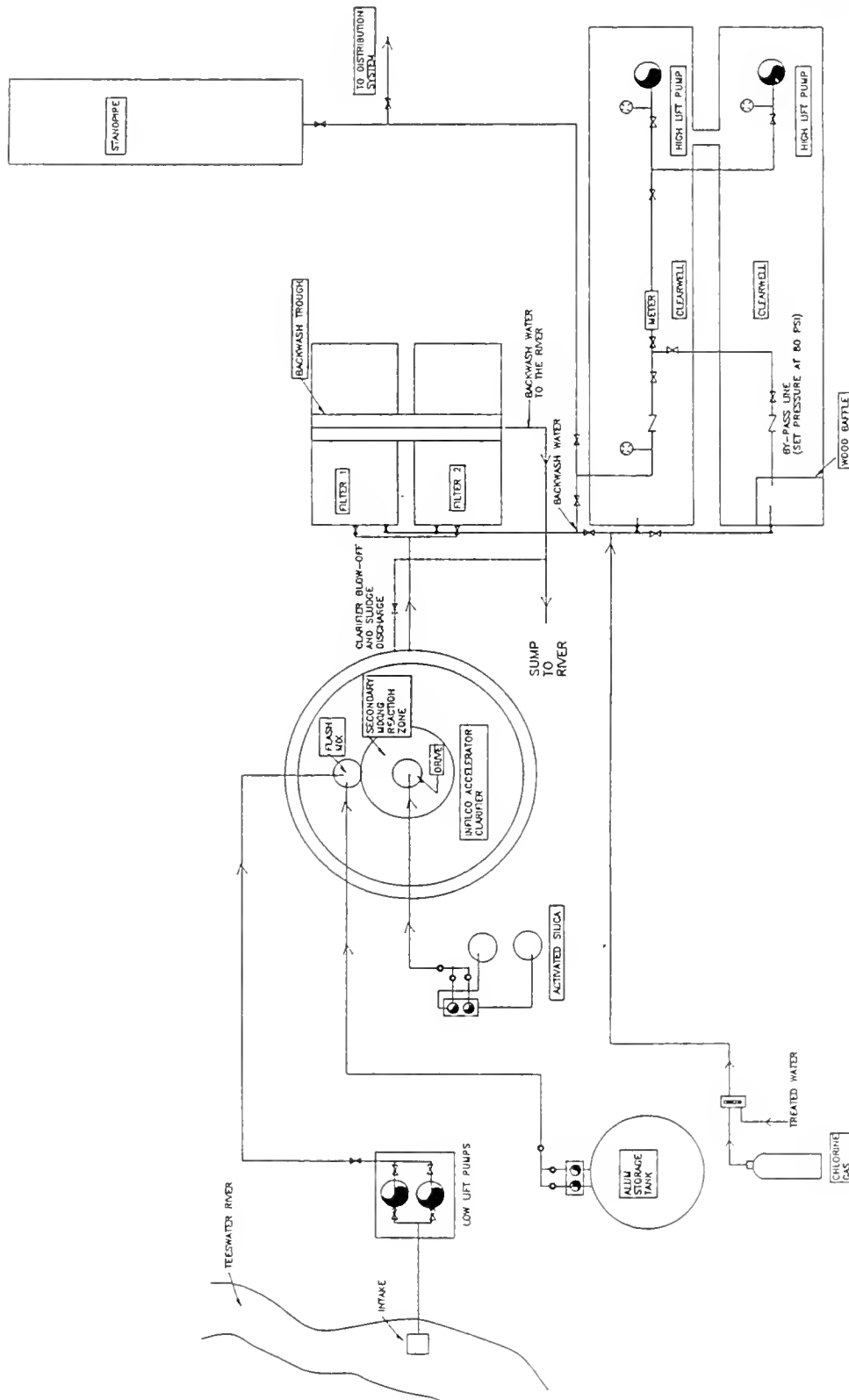
The raw water characteristics for July and August 1996 are:

Colour:	17 to 31 TCU
Turbidity:	4 to 6 NTU
pH:	8.4
Alkalinity:	211 mg/L - CaCO ₃

Plant flows are generally:

Average day:	568 m ³ /d (0.13 MIGD)
Maximum daily flow:	840 m ³ /d (0.19 MIGD) over 11 hours/day
Design capacity:	1,504m ³ /d(0.33MIGD)

- LEGEND
- GATE VALVE
 - BALL VALVE
 - PRESSURE GAUGE
 - CHECK VALVE
 - SLUDGE/BACKWASH LINE
 - WATER LINE
 - PUMP



RAL ENGINEERING LTD.
WATER SUPPLY & WASTEWATER ENGINEERING
142 Queen Street, Newcastle, North Tyne

TITLE

PAISLEY WATER
TREATMENT PLANT
SCHEMATIC

SCALE

NTS

FIGURE

3.1

3.1 TREATMENT UNITS

In general the plant was operating well. It was noted however, that cold weather performance was sometimes a problem in that floc carry over to the filters became common. A brief description of the process unit operations associated with the plant are:

3.1.1 Low Lift Pumps

Two self priming centrifugal pumps at a nominal flow rate of 18.9 L/s (250 IGPM) each.

3.1.2 Mixing

Flash mix installed immediately before the clarifier.

3.1.3 Flocculation

One secondary mixing and reaction zone with two rotor impellers. The diameter of the flocculation chamber is 2.4 m.

3.1.4 Sedimentation

Number:	1
Type:	Infilco Accelerator upflow solids contact
Tank Dimensions:	5.7 m (18.7 ft) diameter
Upward Rise Rate:	3.0 m/h (1 IGPM/ft ²) at 1,504 m ³ /d (design capacity)

3.1.5 Filtration

Number:	2
Type:	Gravity dual media (sand/anthracite) filters
Dimensions:	2.4 m by 3.6 m by 2.4 m deep (8 ft by 12 ft by 8 ft deep) (overall dimensions)
Filtration Rate:	7.25 m/h (2.4 IGPM/ft ²) approximately at design capacity

3.1.6 Clearwell/Standpipe

164 m³ (36,000 IG) baffled clearwell
7.8 m by 3.8 m by 5.5 m (25.5 ft by 12.6 ft by 18 ft)

2,300 m³ (515,000 IG)
9.1 m diameter by 36 m high (30 ft dia. by 118 ft high).
1,137 m³ (250,000 IG) useful volume for the standpipe
17.3 m (57 ft) working depth

3.1.7 High Lift Pumps

Two vertical turbine pumps at a nominal flow of 18.9 L/s (250 IGPM) each.

3.1.8 Wastewater Disposal

Filter backwash and clarifier sludge are discharged to the river.

3.2 CHEMICAL FEED SYSTEMS

The chemical feed systems are:

<u>Process Function</u>	<u>Chemical</u>	<u>Location Added</u>
Primary coagulant:	Liquid alum	Raw water/flash mix
Coagulant aid:	Activated silica	Secondary mixing reaction zone
Disinfection:	Chlorine gas	Filter effluent

3.2.1 Alum

Two Prominent diaphragm pumps manually adjusted.

3.2.2 Activated Silica

Two Masterflex peristaltic pumps manually adjusted.

3.2.3 Chlorine Feed

One wall mounted W&T A-741 chlorinator. Maximum flow 22.7 kg (50 lbs) per 24 hours.
Dosage point after filtration and before clearwell paced on plant flow.

3.3 PLANT CONTROL

The elevation of the highest consumers dictates that the standpipe must be operated at close to maximum level. A slightly lower standpipe level triggers highlift pumping which continues until the standpipe is re-filled or a low level sensor in the clearwell trips the pump power supply. Lowlift operation is triggered by clearwell level sensing. Filter backwash can be set on manual or may be initiated by head loss. Clarifier blow down is operated on a timer system which is energized together with the low lift pumps. The chemical feeds are also started and stopped simultaneously with low lift pump operation.

3.4 HISTORICAL DATA

THM analyses were performed for the Paisley Water Treatment Plant by the MOEE's Drinking Water Surveillance Program (DWSP) in 1995 and 1996. The results are summarized as follows:

	(Sept. 95)	(Nov. 95)	(Jan. 96)	(Feb. 96)	(July 96)
• THM - Treated Water ($\mu\text{g/L}$):	183	189	-	89	128
• THM - Distribution Sys. ($\mu\text{g/L}$):	221	155	61	60	107

Pre-chlorination was practiced at the plant in the past until December 1995, causing high levels of THMs. The highest level was observed in November 1995, with 221 $\mu\text{g/L}$ in the distribution system. The average level of THM in the treated water from January to July 1996 after stopping pre-chlorination was 109 $\mu\text{g/L}$, and 76 $\mu\text{g/L}$ in the distribution system. Stopping pre-chlorination resulted in lower THM formation. However, THM values higher than 100 $\mu\text{g/L}$ are expected during the summer.

A summary of historical data collected in 1995 by plant staff for the turbidity and colour for the raw and the treated water is presented in Table 3.1. The annual average values for 1995 are summarized as follows:

- Turbidity - Raw Water: 7.0 NTU
- Turbidity - Treated Water: 0.17 NTU
- Colour - Raw Water: 82 TCU
- Colour - Treated Water: 1 TCU

The variation of turbidity in the raw and the treated water for 1995 is presented in Figure 3.2. High turbidity peaks for the raw water were observed in January, March and November with a maximum of 14 NTU in November. The turbidity of the treated water remains fairly constant over the year and varies between 0.1 to 0.4 NTU. This is close but still higher than the objective this study is aiming for with 0.1 NTU for the filter effluent.

The variation of colour in the raw and the treated water for Paisley plant is presented in Figure 3.3. The colour for the raw water varies a lot through the year (35 to 123 TCU). The Teeswater River is greatly subject to quality deterioration after heavy rains and during spring time. However, the treated water quality remains fairly constant with an annual average of 1 TCU, which is below the Ontario Drinking Water Objective of 5 TCU. However, it appears that the colour in the treated water for 1995 is low compare to additional analysis performed in July and August 1996 (Table 4.1), where the average colour measured for the two summer months in the treated water was 4 TCU. Analysis performed by the London Regional MOEE lab in 1994 and 1995 also show that the colour in the treated water varies from 2 to 6 TCU.

Analytical results for aluminum residual from 1994 to 1996 are presented in Table 3.2 and Figure 3.4. The MOEE records showed occasional exceedence of the aluminum operational guideline of 100 µg/L in the treated water (320 µg/L in June 1994 and 150 µg/L in November 1995).

TABLE 3.1 PAISLEY WATER TREATMENT PLANT
MONTHLY AVERAGE WATER QUALITY RESULTS - 1995
WATER SAMPLES ANALYZED BY THE WTP STAFF

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVERAGE
TURBIDITY - RAW WATER (NTU)	10.90	1.94	11.30	7.21	8.00	6.02	7.11	7.00	3.42	4.25	14.00	3.15	7.03
TURBIDITY - TREATED WATER (NTU)	0.15	0.12	0.11	0.10	0.16	0.16	0.13	0.17	0.12	0.21	0.38	0.18	0.17
COLOUR - RAW WATER (TCU)	96	35	99	85	107	105	97	96	39	60	123	48	82
COLOUR - TREATED WATER (TCU)	1.6	0.6	0.3	0.7	2	1.3	0.3	0.2	0	0.3	0.8	0	0.7

TABLE 3.2 ALUMINUM RESIDUAL (ug/L)
FOR PAISLEY WATER TREATMENT PLANT
WATER SAMPLES ANALYZED BY MOEE - DWSP

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVERAGE
RAW WATER - 1996	21	39	—	200	—	—	—	—	—	—	—	—	87
TREATED WATER - 1996	48	57	—	21	—	—	—	—	—	—	—	—	42
RAW WATER - 1995	36	—	33	78	73	33	64	49	39	—	100	60	57
TREATED WATER 1995	24	—	44	37	45	71	100	87	100	58	150	29	68
RAW WATER - 1994	22	31	42	140	—	45	88	67	—	—	730	—	146
TREATED WATER - 1994	41	49	28	36	—	320	77	60	—	—	52	—	83

FIGURE 3.2 PAISLEY WTP - RAW AND TREATED WATER TURBIDITY FOR 1995 (ON-SITE)

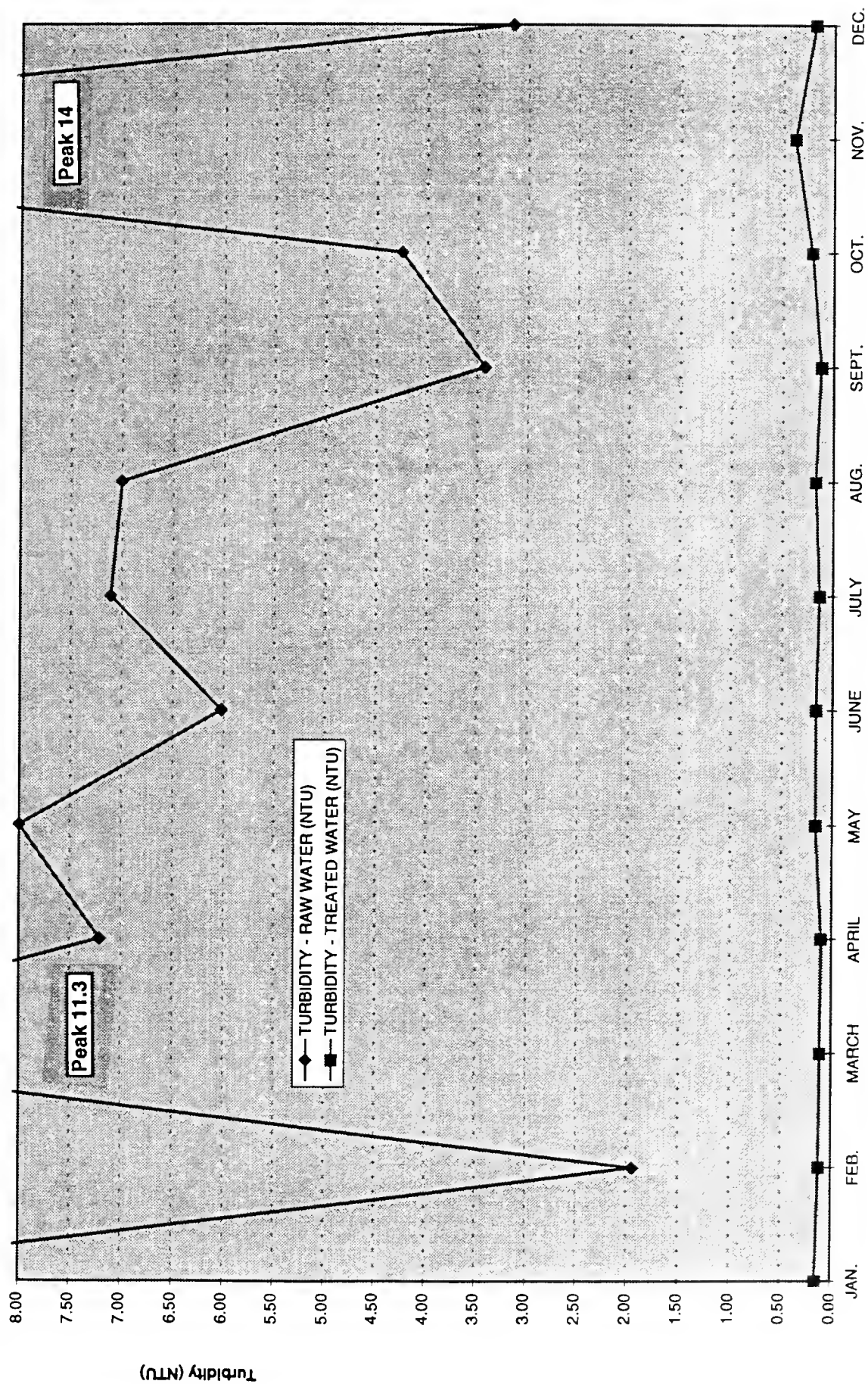


FIGURE 3.3 PAISLEY WTP - RAW AND TREATED WATER COLOUR FOR 1995 (ON-SITE)

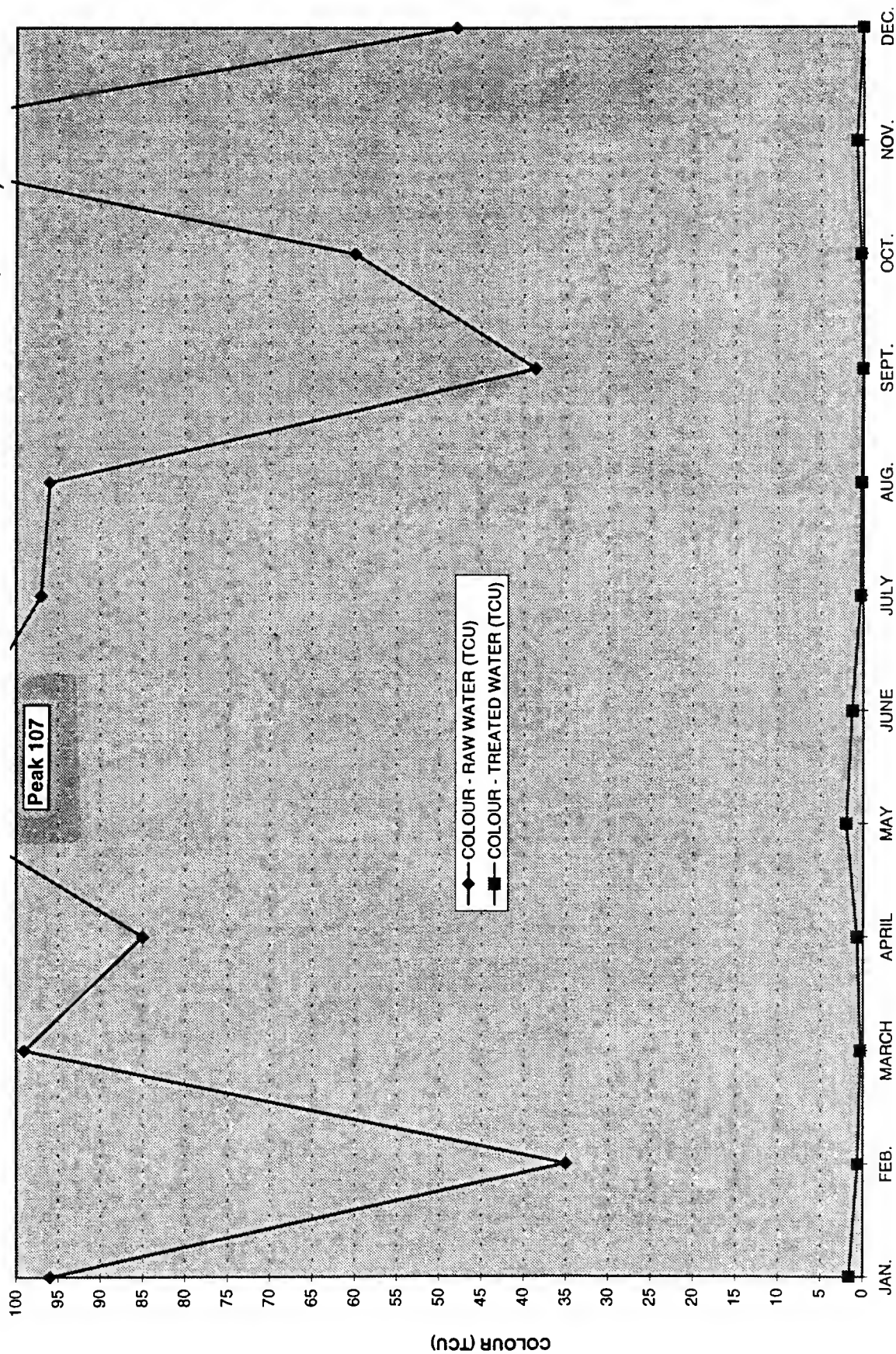
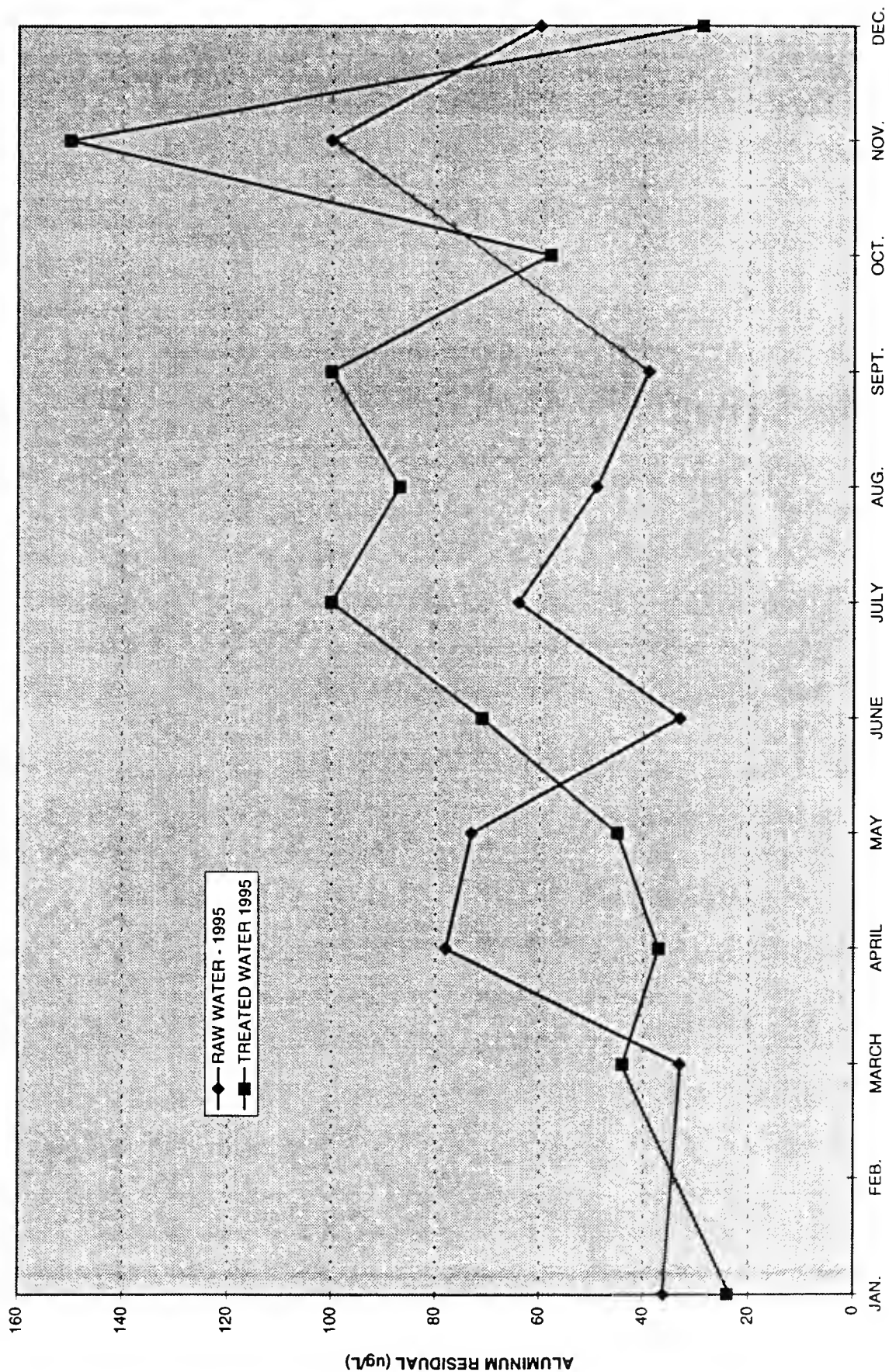


FIGURE 3.4 ALUMINUM RESIDUAL FOR PAISLEY WTP - 1995 (DWSP)



4.0 PERFORMANCE ASSESSMENT

4.1 FINISHED WATER QUALITY

Additional water samples were collected at the treatment plant in July and August 1996 to establish a baseline for THMs versus the level of colour and Total Organic Carbon (TOC). The samples were analyzed by Novamann Laboratories. The results obtained from 5 weeks of sampling are summarized in Table 4.1. The operation data collected at the water treatment plant for the days of sampling including average daily flow, turbidity, raw water temperature and chemical dosages and residuals are presented in Table 4.2.

4.1.1 Colour and Turbidity

The average colour measured during the summer sampling is 22 TCU for the raw water, and the colour in the treated water ranged from 1 to 5 TCU. The colour in the treated water can probably be improved by lowering the pH of the raw water (presently pH 8.2 to 8.5). The high pH would suggest acidification may be required to depress the pH into the effective colour removal range. This could be done with an acidified alum or a separate feed of sulfuric acid or carbon dioxide.

Performance of the plant is generally good for turbidity with results measured at the plant ranging from 0.19 to 0.21 NTU. The turbidity of the treated water measured by Novamann is higher and ranges from 0.2 to 1 NTU. It is normally recommended to perform turbidity testing on-site, since this parameter can increase with time.

4.1.2 THM

The average THM values during the summer sampling for the treated water at the plant and the water in the distribution system are 124 µg/L and 112 µg/L respectively. The results exceed the new ODWO of 100 µg/L for THMs during the summer, but the quarterly annual average for THM level should be under the 100 µg/L ODWO because of slow formation during cold water periods.

Based on THM, colour and TOC analysis performed for Paisley Water Treatment Plant, there is no evidence of a direct relation between the level of colour or TOC in the water and the level of THM formed. The lack of THM-colour correlation is somewhat unexpected since in general the higher the colour, the higher the organic content, therefore producing higher THMs. In addition to the limited number of samples collected, other factors which may have contributed to the lack of correlation include the narrow range of colour value observed, and the analytical variability for THM analysis. The detection limit of the analytical procedures and the method reference used by Novamann is summarized in Appendix F.

The water samples taken in the distribution system for THM analysis were quenched with sodium thiosulfate to remove any chlorine residual and stop any further reaction between free chlorine and organics. This is more representative of what people consume. Quenched water samples will maintain the same level of THM as existed at the time of sampling. The water samples taken at the water treatment plant for THM analysis were not quenched, the reason being to simulate the effect of additional contact time in the distribution system versus the development of THM.

Prior to activities reported under this program, the plant had ceased the practice of pre-chlorination at the intake. The plant was chlorinating the raw water to reduce bacteriological growth on the equipment and more specifically on the filter. Since the plant stopped pre-chlorination, no unusual maintenance problems were reported. Stopping pre-chlorination had led to a reduction of THM levels to just over the new objective of 100 µg/L. Since the objective is based on a four quarter running average and THM formation always drops in cooler weather, the objective will likely be met. On-site measurements using an AccuSensor ORS Environmental System analyzer in September 1996, confirmed that levels did not exceed 65 µg/L even in water leaving the standpipe. This confirms that the THM objective had been reached by the plant personnel on their own initiative.

4.1.3 Aluminum Residual

The MOEE records showed occasional exceedence of the aluminum ODWO operational guideline of 100 µg/L aluminum residual (Table 3.2). This could be due to carryover of particulate aluminum or due to solubility effects whereby delayed precipitation or release from colloidal suspension into solution could occur. Attempts were made to track and correct this aspect of plant performance.

Repeated testing using ECR colourimetric (Erichrome Cyanine R) used by the MOEE, and ICP (Inductively Coupled Plasma Atomic Emission Spectroscopy) used by Novamann both gave erratic results with treated water whether the samples were preserved with nitric acid at sampling time or not. Aging of preserved samples also produced marked effects with aluminum concentrations falling by ECR determination with storage period. These difficulties had not been satisfactorily resolved by mid-December, 1996. It is suspected that the presence of activated silica may be responsible for inaccurate readings.

4.1.4 Fecal Coliform

Based on sampling performed from 1989 to 1992 by the MOEE, Fecal Coliform bacteria organisms were occasionally identified in samples from the distribution system. All sampling of the raw water showed high Total and Fecal Coliform organisms in the river. This indicates the necessity of maintaining appropriate particle removal and disinfection of the water at all times.

4.1.5 Taste and Odour

There were some complaints made about taste and odour during summer. Because the standpipe is operated at high level to maintain pressure and since the inlet pipe also serves as an outlet, there is little water turnover. The water last entering the pipe being the first to be removed. This may cause some water quality deterioration in warmer conditions but there was no way to check this under the current project. This aspect is not part of the main goals and objectives of this study.

4.1.6 Conclusions

With the exception of aluminum and colour, the treated water meets the Ontario Drinking Water Objectives. Analysis of water samples obtained from July and August 1996 sampling identified colour as high as 5 and 6 TCU at the treatment plant and in the distribution system. This is slightly in excess of the objective set out in the ODWO limit of 5 TCU. The colour is classified as an aesthetic parameter and is not health related.

Regarding the aluminum residual, the MOEE records showed occasional exceedence of the aluminum ODWO operational guideline of 100 µg/L. It is suspected that the presence of activated silica may be responsible for unreliable readings, therefore the frequency of exceedences is not known but is likely to be more frequent than indicated.

The plant effluent turbidity for the summer 1996 ranges from 0.19 to 0.21 NTU. Historical data collected in 1995 for the treated water shows that the turbidity ranges from 0.2 to 0.4 NTU. This is below the ODWO for turbidity of 1 NTU. Disease outbreaks caused by giardia and cryptosporidium have been reported with increased frequency over the last decade. These protozoan parasites (especially cryptosporidium) are more difficult to kill with disinfectants, and therefore their removal by physical processes is vital. Current US research and experience now indicates that a turbidity of 0.1 NTU in filter effluent is needed to provide protection from cryptosporidium. Improvement should be made at the plant to reduce floc carried over from the clarifier to the filter to aim for a turbidity of 0.1 NTU.

**TABLE 4.1 JULY AND AUGUST SAMPLING FOR PAISLEY WATER TREATMENT PLANT
WATER SAMPLES ANALYZED BY NOVAMANN**

PARAMETERS	WEEK 1 (10/07/96)	WEEK 2 (17/07/96)	WEEK 3 (24/07/96)	WEEK 4 (07/08/96)	WEEK 5 (14/08/96)	MINIMUM (10/07/96)	MAXIMUM (17/07/96)	AVERAGE (24/07/96)
Turbidity - Raw Water (NTU)*	3.6	4.2	4.8	5.5	5	3.6	5.5	4.6
Turbidity - Treated Water (NTU)*	0.4	1	0.2	0.5	0.9	0.2	1	0.6
Colour - Raw Water (TCU)	22.3	17.2	18.9	31.3	20.4	17.2	31.3	22.0
Colour - Treated Water (TCU)	4	1	4	5	4	1	5	4
Colour - Distribution System (TCU)	5	6	4	6	6	4	6	5
pH - Raw Water	8.48	8.4	8.38	8.54	8.2	8.2	8.54	8.4
pH - Treated Water	8.23	7.85	7.76	8.12	7.64	7.64	8.23	7.92
Alkalinity - Raw Water (mg/L - CaCO ₃)	218	213	196	215	215	196	218	211
Alkalinity - Treated Water (mg/L - CaCO ₃)	200	198	188	200	186	186	200	194
TOC - Raw Water (mg/L)	4.5	3.9	3.4	5.7	4	3.4	5.7	4.3
TOC - Treated Water (mg/L)	2.9	2.6	2.4	4	2.9	2.4	4	3.0
TOC - Distribution System (mg/L)	3.3	2.9	2.7	3.9	3.3	2.7	3.9	3.2
TTHM - Unquenched Treated Water (ug/L)	120	130	120	130	120	120	130	124
TTHM - Quenched Distribution System (ug/L)	110	110	110	120	110	110	120	112

NOTE *: Unreliable results unless measured at time of sampling.

TABLE 4.2 JULY AND AUGUST SAMPLING FOR PAISLEY WATER TREATMENT PLANT
OPERATION DATA COLLECTED AT THE WTP

PARAMETERS	WEEK 1 (10/07/96)	WEEK 2 (17/07/96)	WEEK 3 (24/07/96)	WEEK 4 (07/08/96)	WEEK 5 (14/08/96)	MINIMUM	MAXIMUM	AVERAGE
Average Daily Flow (m3/d)	639	796	702	746	1,035	639	1035	784
Turbidity - Raw Water (NTU)	4.82	N/A	6.87	8.13	7.68	4.82	8.13	6.88
Turbidity - Treated Water (NTU)	N/A	0.21	N/A	0.18	0.19	0.18	0.21	0.19
Temperature - Raw Water (Degree Celsius)	17.8	22	22	23	19	18	23	21
Free Chlorine Residual (mg/L)	2	1.2	1.4	1.4	2	1.2	2	1.6
Total Chlorine Residual (mg/L)	2	1.8	1.8	1.8	2	1.8	2	1.9
Alum Dosage (mg/L)	40	36	47	46	36	36	47	41
Activated Silica Dosage (mg/L)	4.2	4.4	4.3	4.4	4.2	4.2	4.4	4.3
Chlorine Dosage (mg/L)	4.2	3.9	3.6	4.2	4.2	3.6	4.2	4.0

N/A: Not Available

4.2 UNIT PROCESS EVALUATION

The average daily flow was 568 m³/d and the maximum daily flow was 840 m³/d. The rated capacity of the treatment process is 1,504 m³/d. However, the plant is currently operated only 8 to 11 hours per day. The effective maximum flow rate is therefore 840 m³/d X 24/11 or 1,830 m³/d. This is 122% of design capacity during the active operating period.

While the Paisley Water Treatment Plant effluent quality is generally within the MOEE guidelines there are periods of turbidity and colour excursions and inconsistent performance. This indicates a lack of control on the process which could lead to a breakthrough of harmful microorganisms. The practice of operating the plant at a relatively high rate for a short period of time contributes to the unstable treatment process. In particular, the operating characteristics of the solids contact clarifier are such that it performs best under steady state conditions. This type of clarifier is sensitive to up-sets due to hydraulic surges that occur at start-up, and can lose the sludge blanket suspension necessary for effective flocculation when flow is stopped even if the mixer remains on. The performance of clarifiers will always improve when flow is slowed to the lowest rate possible.

Evidence has been accumulated with the help of plant staff over the months of November and December 1996, to show that water leaving the clarifier has a highly variable amount of floc in it. This floc carry over is particularly observed with cooler water temperatures when the floc forming chemical reaction slows down and the water density increases. High floc content in the water generally leads to high turbidity in water output and to aluminum residual in the treated water that exceeds the MOEE operational guideline of 100 µg/L. It is believed that this operational problem constitutes a danger to health because harmful organisms in the raw water may pass into the distribution system during the high floc carry over periods.

It is strongly recommended that the raw water flow be throttled to a rate that will have the plant operate 20 to 24 hours. This can be accomplished through throttling of the raw water flow, with the necessary adjustment of the chemical feeds. Throttling of a centrifugal pump will not cause damage to

it provided a minimum flow of approximately 25% of the rated pump capacity is maintained. Alternatively the existing low lift pumps could be retrofitted with a variable frequency drive that will permit variable speed operation. This type of controller has become readily available over the last five to ten years and offers an inexpensive and very energy efficient method of controlling flow.

4.2.1 Sedimentation

The actual clarifier surface overflow rate must take into account the hours of operation. At maximum day flows the plant only operates 10 to 11 hours. The equivalent daily flow rate is therefore $840 \times 24/11 = 1830$. The Surface Overflow Rate (SOR) at maximum day is:

$$\begin{aligned}\text{Clarifier SOR} &= 1,830 \text{ m}^3/\text{d} \div \text{Clarifier area} \\ &= 1,830 \text{ m}^3/\text{d} \div [(\text{PI} \times (5.7)^2/4) - (\text{PI} \times (2.4)^2/4)] \\ &= 85 \text{ m/d or } 3.5 \text{ m/h. over a 11 hour period}\end{aligned}$$

The MOEE Design Guidelines (MOE, 1982) suggest typical surface overflow rates for sedimentation tanks from 38.4 m/d to 57.6 m/d. The clarifier surface overflow rate therefore considerably exceeds the MOEE criteria when the plant is operated in a 11 hour period only.

4.2.2 Filtration

The filter loading rate for the maximum daily flow is evaluated as follow:

$$\begin{aligned}\text{Loading rate} &= 1,830 \text{ m}^3/\text{d} \div \text{Filter Area} \\ &= 1,830 \text{ m}^3/\text{d} \div (2.4 \text{ m} \times 3.6 \text{ m overall area}) \\ &= 211 \text{ m/d or } 8.8 \text{ m/h (approximately) over an 11 hour period.}\end{aligned}$$

The MOEE Design Guidelines for maximum filtration rate allowed is from 216 to 432 m/d (9 to 18 m/h). The filtration rate for Paisley Water Treatment Plant is considerably lower than criteria recommended by the MOEE for the maximum day flow.

4.2.3 Disinfection

Disinfection of drinking water is the most important aspect of the treatment process. Harmful organisms in water such as bacteria, viruses or cysts can cause illness ranging from minor intestinal disorders to potentially fatal infections. Maintaining an effective disinfection system must be the overriding priority of the plant operations. For surface waters, chlorination with a 'free' residual is the most common and most practical method of disinfection. To be effective, the treated water must be very low in turbidity as suspended particles can shield bacteria and virus from the effect of chlorine. Even turbidity levels greater than 0.1 NTU can indicate an increased probability of chlorine resistant cysts being present.

To achieve a safe level of disinfection, it is necessary to dose the treated water with a sufficient amount of chlorine to produce a 'free' residual, and to give the chlorine sufficient time to inactivate the potentially harmful organisms. This is called the concentration-time factor or CT, also referred to as the primary disinfection stage. Sufficient CT must be achieved at the treatment plant before the first service connection. Current MOEE guidelines call for a minimum residual of 0.5 mg/L for a minimum contact time of 30 minutes after filtration. This disinfection guideline for water treatment plants in Ontario is under review, and the new guideline may be similar to the Surface Water Treatment Rule (SWTR) promulgated by U.S. Environmental Protection Agency (U.S. EPA). The SWTR established CT values for chlorine, chlorine dioxide, ozone and chloramines required to achieve adequate inactivation of giardia cysts and viruses. For the purpose of calculating CT value, T is the time (in minutes) it takes the water, during peak plant flows, to move between the point of disinfectant application and a point where, C, residual disinfectant (in mg/L) concentration is measured just prior to the first customer. The calculation must take into account the degree of short circuiting in the storage tank.

For free residual chlorination, the CT required is based on the inactivation of giardia cysts in cold water. Giardia cysts are harder to inactivate by free chlorine than viruses, therefore, it is implied that proper inactivation of giardia cysts will ensure inactivation of viruses. Disinfection is not effective for the inactivation of cryptosporidium therefore, there is a necessity to perform adequate filtration at the water treatment plant.

Secondary disinfection refers to the maintenance of a residual in the distribution system to protect against bacterial re-growth or minor cross connection contamination. This maintenance residual is commonly achieved with 'free' chlorine, but alternatively can be converted to chloramine or 'combined' residual with the addition of ammonia. Chloramines have the advantage of being more stable and lasting much longer in the system. They also do not react with organics to form THMs. They are however, much less effective as a disinfectant and are very weak in inactivating viruses and cysts. Use of chloramine as a primary disinfectant is therefore not recommended.

The MOEE guidelines recommend a minimum free chlorine residual of 0.2 mg/L at the end of the distribution system. The AWWA recommends a residual of 1.0 mg/L of chloramine be maintained to prevent re-growth (AWWA, 1993). These chlorine residuals do not take into consideration water characteristics such as temperature and pH that affect disinfection efficiency.

According to the SWTR, all community and noncommunity public water systems which use a surface water source or a ground water under the direct influence of a surface water must achieve a minimum of 99.9 percent (3-log) removal and/or inactivation of giardia cysts. According to these guidelines, systems with sewage and agricultural discharges to the source water should provide treatment to achieve an overall 5-log removal/inactivation of giardia cysts, while the minimum required 3-log removal/inactivation is sufficient for sources with no significant microbiological contamination from human activities, a 4-log removal/inactivation of cysts should be provided for source waters whose level of microbiological contamination is between these two extremes.

Because of the impact of sewage discharge and agricultural activities on the Teeswater River upstream of Paisley, it is recommended to use 5-log reduction. Sampling of the river supply performed from 1989 to 1992 by the MOEE showed high Total and Fecal Coliform counts. Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of giardia cysts. The required CT will be based on 2.5-log inactivation of giardia cysts (5.0 - 2.5-log).

Examples of CT calculations for winter and summer conditions are presented in Appendix B. The contact time (T) in the clearwell is estimated by using the actual maximum daily flow when the plant is operated 11 hours per day for the winter and the summer conditions. It is expected that the peak hourly rate will be provided by the standpipe located in Town. As a conservative approach, T is evaluated under the worst case scenario where the clearwell level is half full.

Based on the "Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Source" (U.S. EPA, 1990), the baffle condition in the clearwell expressed as T_{10}/T factor can be evaluated to estimate the effective contact time in the clearwell. This factor represents the ratio between T_{10} , which is the time it takes 10 percent of a dye or tracer to be detected at the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mix chamber.

When tracer studies are not available, a description of the clearwell and baffling condition can be used to estimate the T_{10}/T factor. The clearwell for Paisley treatment plant has one inlet baffle made of wood and a concrete baffle separating the clearwell in two sections. The cells have no intra-basin baffles. This clearwell is qualified as below average baffling condition. Therefore, the T_{10}/T factor is 0.4. An average baffling condition ($T_{10}/T = 0.5$) is described as baffled inlet or outlet with some intra-basin baffles. The results of the evaluation of residual chlorine concentration required for inactivation of giardia cysts under various conditions (Appendix B.1 to B.6) are summarized in Table 4.3.

TABLE 4.3 Calculation of minimum residual chlorine concentration necessary for inactivation of giardia cysts

CONDITIONS	FREE RESIDUAL CHLORINE CONCENTRATION (MG/L) C	CONTACT TIME (MINUTES) T
Winter condition with the clearwell ½ full, and the plant operated 11 h/d.	>3	34
Summer condition with the clearwell ½ full, and the plant operated 11 h/d.	>3	21
Winter condition with the clearwell ½ full, and the plant operated 24 h/d.	>3	74
Summer condition with the clearwell ½ full, and the plant operated 24 h/d.	1.6	46
Winter condition with the clearwell ½ full, the plant operated 24 h/d, and the clearwell is baffled.	1.8	130
Summer condition with the clearwell ½ full, the plant operated 24 h/d, and the clearwell is baffled.	0.8	80

The results presented in Table 4.3 show that a free chlorine residual greater than 3 mg/L would be required to provide adequate protection against giardia cysts all year around when the plant is operated 11 hours per day. Such a high level of chlorine residual would translate directly to a high formation of THM exceeding the ODWO of 100 µg/L, and would also not be acceptable to consumers because of taste and odour.

Results from Table 4.3 demonstrate the necessity to lower the actual maximum flow rate by extending the operation of the plant to a full day, to be able to meet the disinfection requirement. However, extending the hours of operation of the plant alone would not be enough, since the free chlorine residual required at the plant during the winter would still be higher than 3 mg/L, generating taste and odour problems.

The most practical and economical approach recommended to meet the disinfection requirement for inactivation of giardia cysts for winter and summer conditions would be to lower the plant flow rate by extending the hours of operation to a full day operation, combined with the installation of baffles in the clearwell. This would improve the overall retention time in the clearwell and reduce short circuiting. The addition of baffles can improve the baffling condition from what is presently considered to be below average condition ($T_{10}/T=0.4$), to a superior baffling condition with a T_{10}/T factor equal to 0.7. A superior baffling condition is described as perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated launders.

The free chlorine residuals to be maintained under these conditions are 1.8 mg/L during the winter and 0.8 mg/L during the summer. Higher free chlorine residual is required during the winter since lower water temperature reduces the rate of inactivation. Information collected from the water plant shows that a free chlorine residual is normally kept between 1.2 to 2 mg/L, which will provide adequate inactivation of giardia cysts

under the proposed modifications. It is noted that to reduce THM formation during the summer, chlorine dosage could be reduced to a free chlorine residual of 1 mg/L for the condition where the plant is operated all day, and after up-grading the baffling condition in the clearwell.

Increasing the hours of operation of the plant will have no impact on overall chemical consumption since the same amount of water is treated over a 24-hour period instead of an 11 hour period per day. Therefore, the existing chemical pumps and chemical storage tanks would remain adequate. It is expected that the operation cost for electrical consumption for the low lift pumps would be a little higher than when the plant is operated 24 hours per day.

5.0 OFF-SITE BENCH SCALE EVALUATIONS

5.1 INTRODUCTION

The off-site bench scale study was conducted by Dr. Edmonds from the MOEE Science & Technology Branch, Water & Wastewater Optimization Section. The primary objective of this study was to determine what combination(s) of treatment chemicals could be tried at plant-scale to improve the performance of the Paisley water plant in terms of colour and turbidity removal.

Various chemicals were examined in order to identify a chemical treatment that would minimize the production of trihalomethanes during treatment. This treatability study was conducted using a conventional mode of treatment consisting of coagulation, flocculation, sedimentation and filtration.

Extensive jar testing of water samples was carried out using a raw water sample taken at the plant in September, 1996. The primary coagulants tested were alum and ferric sulphate (Ferriclear). A total of six polymers were tested in conjunction with the primary coagulant: LT20, LT22, LT24, LT25, 8170 and 8171. Activated silica was also tested as coagulant aid with alum, Ferriclear and polyaluminum chloride (PACL). Sodium silicate was activated with sodium bicarbonate. Detailed results of jar testing are presented in Appendix C.

5.2 CONCLUSIONS AND RECOMMENDATIONS

Results from off-site jar testing show that tests done with ferric sulphate plus a polymer, and with alum and a polymer provided the same level of colour and turbidity removal but neither combination performed as well on turbidity as did alum and activated silica, which are currently used at the plant. No combination of coagulant and coagulant aid was found which exceeded the performance of the presently used alum and activated silica combination. Based on the results from off-site testing, the utilization of activated silica should continue.

6.0 ON-SITE TESTING EVALUATIONS

6.1 UPSTREAM INJECTION OF ALUM

The Paisley plant was visited during the fall 1996 by Dr. Edmonds of the MOEE. Prior experience suggested better settling performance might be achieved by alum injection immediately downstream of the low lift pumps. This would provide several seconds for turbulent mixing in the 6 meters (20 feet) of piping leading to the clarifier inlet. This was set up with a suitable pump loaned by the MOEE.

A revised results recording sheet was made up by the MOEE and provided to the plant personnel. Daily reports were prepared by the plant staff from November 10 to December 13, 1996. The results for turbidity as a function of alum injection point are presented in Appendix D. The analysis of the results is not simple to make for two reasons:

- 1- The timing of reading instruments was not controlled, and the clarifier was operating only over short periods in a disturbed mode rather than in steady state condition. There may have been additional statistical "noise" included in the data.
- 2- The time period over which results were collected is too short for really firm conclusions with the "noise" present due to the natural source water variations and the factor above.

Despite these factors, cursory observation shows high finished turbidity excursions to over 0.4 NTU occurred once with alum injection immediately downstream of the lowlift pumps, as opposed to four times with the regular drip feed of alum into the clarifier intake.

Analysis as a logarithmic distribution using all the data shows a very modest and barely significant reduction in average finished turbidity of about 20%. Analysis as a Gaussian distribution with one highest outlier removed from each data set suggests a 37% improvement. It is concluded that there is support for a modest improvement in performance by using upstream injection. It is also important to add that the injection of alum immediately downstream of the low lift pumps into a static mixer will improve further the dispersion of alum into the pressure line. This would help the alum to enter in contact with particulates present in the raw water.

6.2 JAR TESTING WITH COLD WATER

It was stated that cold weather performance was sometimes a problem in that floc settling became very slow. This was suspected to be a cause of high aluminum levels. Slow floc formation was witnessed in late November during jar testing performed at the plant with a raw water temperature of 3 °C. Laboratory tests using iron coagulant later showed no visible improvement. Mild acidification remains an option to be tried by the plant to lower the pH and lower the aluminum residual in the treated water.

7.0 CONCLUSIONS

Paisley Water Treatment Plant is not in compliance with the 100 µg/L Ontario Drinking Water Objective for THMs in the distribution system during the summer months with values in the 110 to 120 µg/L region. It is expected however, that the annual running average of 4 quarterly samples will likely be close to the new guideline, since low levels were reported for the winter (61 µg/L in the distribution system in January 1996, 60 µg/L in the distribution system, and 89 µg/L at the water treatment plant for February 1996). It will then be important to monitor the level of THM during 1997 to verify that Paisley is in compliance with the 100 µg/L ODWO for THM.

Disinfection requirements for inactivation of giardia cysts and viruses can not be met for the summer and the winter conditions when the plant is operated only 11 hours per day. This would require very high chlorine residual that would generate taste and odour problems, and create higher levels of THMs. It is believed that this operational problem constitutes a danger to health for the residents of Paisley, because harmful organisms in the river may pass into the distribution system during high floc carry over since the clarifier is operated at too high a water throughput rate in short, two hour bursts. It has been recommended to reduce the flow to the clarifier by providing a 20 to 24 hour plant operation. This operational modification would also have to be combined with the installation of baffles in the clearwell. The installation of baffling would increase the retention time of the water in the clearwell therefore, allowing lower chlorine dosage for proper inactivation of cysts and viruses.

Historical data for turbidity of the treated water ranges from 0.2 to 0.4 NTU. This is below the ODWO for turbidity of 1 NTU. However, disease outbreaks caused by *Giardia* and *cryptosporidium* have been reported with increased frequency over the last decade in Canada. These protozoan parasites (especially *cryptosporidium*) are more difficult to kill with disinfectants, and therefore their removal by physical processes is vital. As a result, Health Canada is now examining the need for stricter standards

for particle removal in water plants. Current US research and experience now indicates that a turbidity of 0.1 NTU in filter effluent is needed to provide protection from cryptosporidium. Improvement should be made at the plant to reduce floc carried over from the clarifier to the filter to aim for a turbidity of 0.1 NTU.

The MOEE records showed occasional exceedence of the aluminum ODWO operational guideline of 100 µg/L. This could be due to carryover of particulate aluminum or to solubility effects whereby delayed precipitation or release from colloidal suspension into solution could occur. It is suspected however that the presence of activated silica may be responsible for inaccurate readings. Therefore, the actual frequency of guideline exceedence is not known.

8.0 RECOMMENDATIONS FOR PLANT SCALE MODIFICATIONS

Short low lift pumping cycles of an hour or two in duration lead to obvious increases in turbidity. This was occurring because of the mismatch between demand and plant operating rate observed in the fall. A proposal to slow pumping to enable more steady operation was presented to the Town. During a phone conversation on Friday, December 13, RAL Engineering/MOEE were informed that it would not be permitted by Paisley Council to reduce the clarifier flow rate without formal agreement that the MOEE would cover the replacement cost of any equipment failure which might occur during the trials no matter what the cause. The Ministry is not able under this project to offer such guarantees.

In the eventuality that the Town review their position about reducing the low lift pump flow and increasing the hours of operation, cost estimates for the purchase and installation of a throttling valve or a variable speed controller are presented in Chapter 9.0. This option would also require the installation of a flow meter for the raw water.

It is believed that reducing the clarifier flow rate would greatly benefit the overall water quality, and is in fact essential to meet the disinfection requirement for a 5-log inactivation of giardia cysts. This operational problem, if not resolved, constitutes a risk to public health, since harmful organisms present in the river may pass through the filters and into the distribution system during high carry over periods.

Further investigations the plant may wish to pursue would involve the use of different commercial coagulant and coagulant aid combinations, and/or acidification (CO₂ or sulfuric acid) or the utilization of acidified alum to improve low temperature floc formation. Another option available is to investigate the possibility to filter to waste after a backwash or on plant start-up to reduce the risk of outbreaks for the community. Proper assessment of these or other process modifications are not possible under the current high rate operations.

Arrangements will be made with Novamann Laboratories to provide additional water testing of the raw water (turbidity, colour, pH, alkalinity and TOC), the treated water (turbidity, colour, pH, alkalinity, TOC, THM and aluminum), and the distribution system (colour, TOC and THM) for 1997. Additional monitoring will be necessary to evaluate if plant performances are in compliance.

9.0 COST ESTIMATE FOR IMPLEMENTATION

Table 9.1 is a summary of capital expenditures involved for the implementation phase. The figures presented are estimates prepared to give an idea of the price range involved. Installation of equipment is included in the cost estimates. The capital cost estimate for plant upgrades is \$43,000, if a throttling valve is used to lower the plant flow or \$48,000, if a variable speed controller is installed to control the low lift pump instead of using a throttling valve.

TABLE 9.1 Capital expenditure

PROPOSED MODIFICATIONS	COST (\$)
Permanent relocation of alum injection point immediately downstream of the low lift pumps with installation of a static mixer and two alum injection pumps (one used as standby)	\$11,000
Throttling valve or variable speed controller for the low lift pump	\$5,000 or \$10,000
Raw water flow meter	\$8,000
Installation of baffles in the clearwell	\$8,000
Installation of turbidimeters and chart recorder	\$8,000
Installation of in-line pH meter	\$3,000
TOTAL (for throttling valve installation):	\$43,000
OR	OR
TOTAL (for variable speed controller installation):	\$48,000

GLOSSARY AND LIST OF ABBREVIATIONS

Alum	: aluminum sulphate
CT and	: Value required to achieve adequate inactivation and/or removal of cysts and viruses. T is the time (in minutes) it takes the water during peak hourly flow, to move between the point of disinfectant and a point where C, the residual disinfectant concentration (mg/L), is measured prior to the first customer.
d	: day
°C	: degree Celsius
DWSP	: Drinking Water Surveillance Program
ECR reagent	: Eriochrome Cyanine R
FID	: Flame Ionization Detector
ft	: foot
G	: flocculation energy gradient
Gt	: flocculation energy
GC/MS	: Gas Chromatograph / Mass Spectrometry
GAC	: Granular Activated Carbon
g	: gram
h	: hour
HFS	: hydroxylated ferric sulphate (Ferriclear)
ICP	: Inductively Coupled Plasma Atomic Emission Spectroscopy
IG	: imperial gallon
kW	: kilowatt
L	: litre
L/cap.d	: litres per capita per day
L/s	: litres per second
m	: metre
m ²	: square metres
m ³	: cubic metres

m ³ /d	: cubic metres per day
m/h	: metres per hour (equivalent m ³ /m ² .h - filtration rate)
µg/L	: micrograms per litre
mg/L	: milligrams per litre
mm	: millimetre
mL/min	: millilitres per minute
min	: minute
NTU	: Nephelometric Turbidity Unit
OCWA	: Ontario Clean Water Agency
ODWO	: Ontario Drinking Water Objective
%	: percent
PACL	: polyaluminum chloride
PVC	: polyvinyl chloride
lb	: pound
rpm	: revolution per minute
SOR	: Surface Overflow Rate
SWTR	: Surface Water Treatment Rule
T ₁₀ /T	: This factor describes the baffling condition in the clearwell, and represents the ratio between T ₁₀ , which is the time it takes 10 percent of a dye or tracer to be detected at the basin outlet after it is injected into the basin influent flow, and the theoretical detention time for plug flow in pipelines and flow in a completely mixed chamber.
TOC	: Total Organic Carbon
THMs	: Trihalomethanes
TCU	: True Colour Unit
W/V	: weight/volume

REFERENCES

American Water Works Association Research Foundation - Optimizing Chloramine Treatment, 1993.

Environmental Science and Engineering Magazine. Drinking water Update - The Facts About Human Health and Aluminum in Drinking Water, January, 1997.

U.S. Environmental Protection Agency, Science and Technology Branch Criteria and Standards Division of Drinking Water. Guidance Manual for Compliance With the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources, October , 1990.

Ontario Ministry of the Environment, Environmental Approvals and Land Use Planning Branch. Guidelines for the Design of Water Treatment Works, April 1982.

APPENDICES

Plant Survey

Appendix A

PLANT: PAISLEY WATER TREATMENT PLANT

Plant Location: Mill Street, Paisley, Ontario

Shipping Address: Box 460, 338 Goldie Street, Paisley, Ontario, N0G 2N0

Tel: (519) 353-5609

Fax: (519) 353-7145

(519) 353-5266 - Plant

PREPARED BY: Line Fortin**DATE:** Plant visit: July 5, 1996**STAFF:**

•Superintendent: Mr. Jerrold Beech

•No. of Operators: 3 including Mr. Beech

•Work Schedule: 7-1/2 h/d, 7 days a week

•Hours of Plant Operation: 9 to 11 h/d

•Names of Operators:

Mr. Ken Anderson, Road Superintendent

Mr. Ronald Osbaldeston

•Certified Y/N: 3 operators certified

PLANT CAPACITY:•Average Daily Flow: 568 m³/d (125,000 lgal/d)•Maximum Daily Flow: 840 m³/d (185,000 lgal/d)•Rated Plant Capacity: 1,504 m³/d (331,000 lgal/d)

(Limiting component: Clarifier & Filter)

•Population Served: 1,200 persons

(Village of Paisley and Elderslie Township)

•Average Daily Flow per Capita: 473 L/pers.d

OPERATING AUTHORITY: Village of Paisley**YEAR OF CONSTRUCTION:** 1976**SOURCE OF RAW WATER:** Teeswater River**RAW WATER CHARACTERISTICS:**

• Colour: 25 to 120 TCU

• Turbidity: 2 to 14 NTU

• pH: 8.2 to 8.5

• Alkalinity: 190 to 220 mg/L - CaCO₃**CHEMICALS:**

• Coagulant: Type: Liquid alum

Dosage: 60 mg/L (Summer), 32 mg/L (Winter)

Injection Point: Clarifier flash mix

• Coagulant Aid: Type: Activated silica

(sodium silicate - 28.7% SiO₂ is activated with sodium bicarbonate)

Dosage: 1 to 4 mg/L

Injection Point: Secondary mixing and reaction zone in the clarifier

• Disinfection: Type: Chlorine gas

Dosage: 5.4 mg/L (Summer), 3 mg/L (Winter)

Injection Point: Filter effluent (Post-disinfection)

ANALYSIS DONE ON-SITE:

• Colour

• Turbidity

• Temperature

LAB EQUIPMENT AVAILABLE:

• DR/700

• 2100P Turbidity meter

PROCESS CONFIGURATION:

CHEMICALS METERING:

<u>TYPE</u>	<u>CAPACITY</u>	<u>CONTROL</u>	<u>CONDITION</u>
• Coagulant:	2 Prominent pumps (one as standby)	Manual adjustment Operation based on plant on/off	Good
• Activated Silica:	2 Masterflex pumps (one as standby)	Manual adjustment Operation based on plant on/off	Good
• Disinfection:	Post-disinfection Wall mounted Wallace & Tiernan A-741 chlorinator Maximum flow: 22.7 kg of chlorine per day	Paced to plant flow	Good
• Other:	N/A		

PROCESS CONFIGURATION (Continued):			
<u>INTAKE:</u>	<u>TYPE</u> Crib located about 5 m from shore, 30 m from plant in 2 m of water. Concrete inlet structure with removable screen. Built in 1981		
<u>LOW LIFT PUMPS:</u>	<u>TYPE</u> 2 Gorman Rupp self priming centrifugal pumps	<u>CAPACITY</u> 18.9 L/s (250 lpm) per pump	<u>CONDITION</u> Good
<u>HIGH LIFT PUMPS:</u>	<u>TYPE</u> 2 Vertical turbine pumps	<u>CAPACITY</u> 18.9 L/s (250 lpm) per pump	<u>CONDITION</u> Good
<u>MIXING:</u>	<u>TYPE</u> Flash Mix installed immediately before the clarifier		
<u>FLOCCULATION:</u>	<u>TYPE</u> 1 Secondary mixing & reaction zone with 2 rotor impellers	<u>DIMENSIONS</u> 2.4 m diameter (8ft)	<u>VOLUME</u>
<u>CLARIFICATION:</u>	<u>TYPE</u> 1 Inflico Accelerator	<u>DIMENSIONS</u> 5.7 m (18.7 ft diameter)	<u>DESIGN RISE RATE</u> 70 m/d (1 IGPM/ft ²) or 2.9 m/h @ Design capacity
<u>FILTERS:</u>	<u>TYPE</u> 2 Gravity Filters Dual media: sand/anthracite Parallel operation	<u>DIMENSIONS</u> 2.4m (8ft) x 3.6m (12ft) x 2.4m (8ft) 0.9m (3ft) of media	<u>DESIGN FILTRATION RATE</u> 7.25 m/h @ Design capacity
<u>CLEARWELL:</u>	<u>NO</u> 1	<u>DIMENSIONS</u> 7.8m (25.5ft) x 3.8m (12.6 ft) x 5.5m (18ft)	<u>VOLUME</u> 164 m ³ (36,000 lgal) 1 concrete baffle
<u>STANDPIPE:</u>	<u>NO</u> 1	<u>DIMENSIONS</u> 9.1m (30ft) diameter x 36m (118ft) high	<u>VOLUME</u> 2,300 m ³ (515,000 lgal) Useful volume: 1,137 m ³ Working depth: 17.3m (57ft)

PLANT CONTROL:

- Level: The water level in the standpipe controls the operation of the high lift pumps. The clarifier, filters and low lift pumps are turned on and off based on the water level in the clearwell.

PROCESS MONITORING:

	<u>INSTRUMENT</u>	<u>MONITORING FREQUENCY</u>	<u>LOCATION</u> <u>NOTES</u>
• Turbidity:	Hach 2100 P Portable Turbidimeter	Daily	•Raw water •Plant effluent
• Free Chlorine Residual:	Not analyzed		
• Total Chlorine Residual:	Hach DR/700 Colorimeter	3 x per day	Plant effluent
• Temperature:	Thermometer	Daily	Raw water
• Colour:	Colour Comparator	Daily	•Raw water •Plant effluent
• Aluminum Residual:	MOEE Lab	Monthly (1994-1996)	•Raw water •Plant effluent

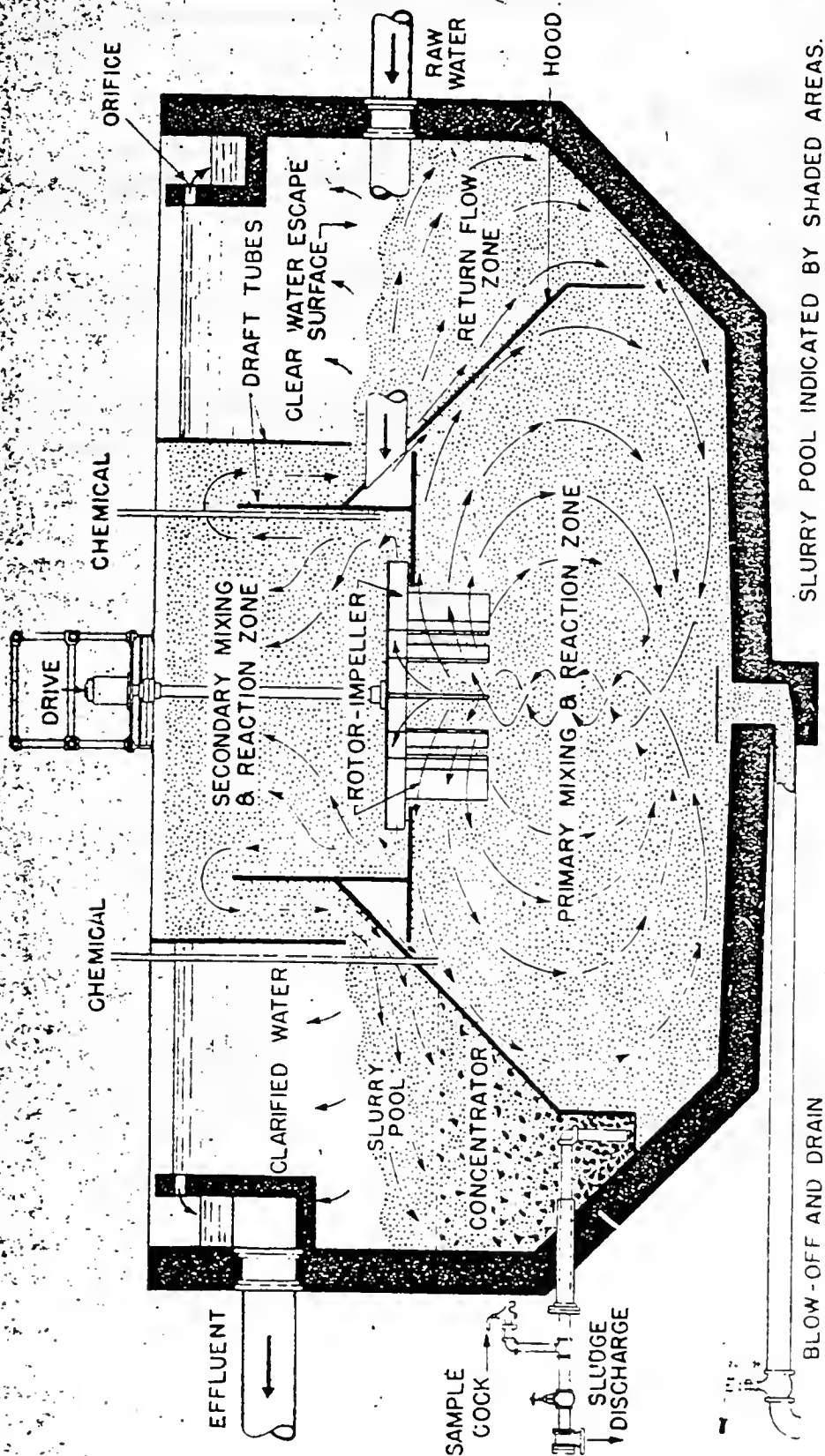
ISSUES:

RAW WATER:

- High levels of colour and turbidity is found in the raw water during rainy weather and spring time.
- The raw water has a high pH level (pH 8.2).
pH adjustment with sulfuric acid or CO₂ could improve the performance of the treatment plant.
- The relocation of the alum injection point from the flash mix to a point closer to the low lift pumps should improve the coagulation/flocculation process.

TREATED WATER:

- With the exception of the organic nitrogen, aluminum and colour concentration, the treated water met the Ontario Drinking Water Objectives.
- Analysis of water samples obtained by MOEE staff in July and August 1992 identified colour (11.0, 9.5 and 11.0 TCU) in the treated water in excess of the objective set out in the O.D.W.O. limit of 5 TCU.
- The aluminum concentration in the treated water leaving the plant exceed MOEE recommended guideline of 100 µg/L. Excessive residual aluminum can result in:
 - distribution system coating with consequent increased energy requirements;
 - after-flocculation leading to consumer complaints.
- Based on sampling performed from 1989 to 1992 by the MOEE, on occasion, Fecal Coliform bacterial organisms were identified in samples from the distribution system. All sampling of the raw water showed high Total and Fecal Coliform organisms in the river. This indicates the necessity of maintaining appropriate disinfection of the water at all times.



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Evaluation of Residual Chlorine Concentration for Inactivation of Giardia Cysts

PAISLEY WATER TREATMENT PLANT

B.1 Evaluation of residual chlorine concentration required for 5-log inactivation of Giardia Cysts during the winter for the clearwell 1/2 full, and the plant operating 11 hours per day:

NOTES:

* The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of Giardia Cysts. However, it is recommended to use 5-log reduction since based on sampling performed from 1989 to 1992 by the MOEE the river supply showed high Total and Fecal Coliform counts.

* Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of Giardia cysts.

CT for 2.5-log inactivation =

Where
C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

$$T = [\text{Volume of Clearwell (m}^3\text{)} \times \% \text{Full} \times \text{Baffling Condition (T10/T)}] / [\text{Maximum Day Flow (m}^3\text{/d)}] \times 1,440 \text{ min/d}$$

Volume of Clearwell = 164 m³

% Full =

$$T_{10}/T =$$

Actual Max. Day Flow

Condition = Winter Time

T = 34 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 2.5-log inactivation / T

CT = 263

C =	7.71 mg/L
-----	-----------

PAISLEY WATER TREATMENT PLANT

B.2 Evaluation of residual chlorine concentration required for 5-log inactivation of Giardia Cysts during the summer for the clearwell 1/2 full and the plant operating 11 hours per day:

NOTES:

- * The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of *Giardia* Cysts. However, it is recommended to use 5-log reduction since based on sampling performed from 1989 to 1992 by the MOEE the river supply showed high Total and Fecal Coliform counts.
- * Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of *Giardia* cysts.

CT for 2.5-log inactivation =

Where
C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

$$T = \frac{[\text{Volume of Clearwell (m}^3\text{)} \times \% \text{Full} \times \text{Baffling Condition (T10/T)}]}{[\text{Maximum Day Flow (m}^3\text{/d)}] \times 1,440 \text{ min/d}}$$

Volume of Clearwell =	164 m3
% Full =	0.5
T10/T =	0.4
Actual Max. Day Flow	1,035 X 24/11
Condition =	Summer Time
	2258 m3/d

T = 21 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 2.5-log inactivation / T⁸⁴

C =	4.02 mg/L
-----	-----------

PAISLEY WATER TREATMENT PLANT

B.3 Evaluation of residual chlorine concentration required for 5-log inactivation of Giardia Cysts during the winter for the clearwell 1/2 full, and if the plant is operated 24 hours per day:

NOTES:

- * The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of *Giardia* Cysts. However, it is recommended to use 5-log reduction since based on sampling performed from 1989 to 1992 by the MOEE the river supply showed high Total and Fecal Coliform counts.
- * Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of *Giardia* cysts.

CT for 2.5-log inactivation = 263 (at 0.5 oC or lower, pH=7.5 and Conc. = 3.0 mg/L) 73 (at 20 oC, pH=8.0 and Conc. = 1.6 mg/L)

Where
C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

$$T = \frac{\text{Volume of Clearwell (m}^3\text{)} \times \% \text{Full} \times \text{Baffling Condition (T10/T)}}{\text{[Maximum Day Flow (m}^3\text{/d)]} \times 1,440 \text{ min/d}}$$

Volume of Clearwell =	164 m3
% Full =	0.5
T10/T =	0.4
Max. Day Flow =	635 m3/d
Condition =	Winter
Time	

T = 74 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 2.5-log inactivation / T₂₆₃

C =	3.54 mg/L
-----	-----------

PAISLEY WATER TREATMENT PLANT

B.4 Evaluation of residual chlorine concentration required for 5-log inactivation of *Giardia* Cysts during the summer for the clearwell 1/2 full, and if the plant is operated 24 hours per day:

NOTES:

* The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of Giardia Cysts. However, it is recommended to use 5-log reduction since based on sampling performed from 1989 to 1992 by the MOEE the river supply showed high Total and Fecal Coliform counts.

* Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of Giardia cysts.

CT for 2.5-log inactivation = 263 (at 0.5 oC or lower, pH=7.5 and Conc. = 3.0 mg/L)
73 (at 20 oC, pH=8.0 and Conc. = 1.6 mg/L)

Where
C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

$$T = \frac{[\text{Volume of Clearwell (m}^3\text{)} \times \% \text{Full} \times \text{Baffling Condition (T10/T)}]}{[\text{Maximum Day Flow (m}^3\text{/d)}] \times 1,440 \text{ min/d}}$$

Volume of Clearwell =	164 m3
% Full =	0.5
T10/T =	0.4
Actual Max. Day Flow	1,035 m3/d
Condition =	Summer Time

T = 46 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 2.5-log inactivation / T₇₃

C = 1.60 mg/L

PAISLEY WATER TREATMENT PLANT

B.5 Evaluation of residual chlorine concentration required for 5-log inactivation of *Giardia* Cysts during the winter for the clearwell 1/2 full, when the plant is operated 24 hours per day and the clearwell is baffled:

NOTES:

- * The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of Giardia Cysts. However, it is recommended to use 5-log reduction since based on sampling performed from 1989 to 1992 by the MOEE the river supply showed high Total and Fecal Coliform counts.
- * Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of Giardia cysts.

CT for 2.5-log inactivation = 233 (at 0.5 oC or lower, pH=7.5 and Conc. = 1.8 mg/L)
66 (at 20 oC, pH=8.0 and Conc. = 0.8 mg/L)

Where
C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

$$T = [\text{Volume of Clearwell (m}^3\text{)} \times \% \text{Full} \times \text{Baffling Condition (T10/T)}] / [\text{Maximum Day Flow (m}^3\text{/d)}] \times 1,440 \text{ min/d}$$

Volume of Clearwell =	164 m3
% Full =	0.5
T10/T =	0.7
Max. Day Flow =	635 m3/d
Condition =	Winter Time

T = 130 Minutes

Evaluation of Residual Chlorine Concentration (C):

$$C = \frac{CT \text{ for 2.5-log inactivation}}{T_{233}}$$

C =	1.79 mg/L
-----	-----------

PAISLEY WATER TREATMENT PLANT

B.6 Evaluation of residual chlorine concentration required for 5-log inactivation of Giardia Cysts during the summer for the clearwell 1/2 full when the plant is operated 24 hours per day with the clearwell baffled:

NOTES:

* The SWTR establishes CTs for chlorine, chlorine dioxide, ozone and chloramines which will achieve a min. of 3-log inactivation of Giardia Cysts. However, it is recommended to use 5-log reduction since based on sampling performed from 1989 to 1992 by the MOEE the river supply showed high Total and Fecal Coliform counts.

* Well operated conventional treatment plants which have been optimized for turbidity removal can be expected to achieve at least a 2.5-log removal of *Giardia* cysts.

CT for 2.5-log inactivation =

Where
C = Concentration (mg/L)
T = Contact Time (min)

Evaluation of contact time (T):

$$T = \frac{[\text{Volume of Clearwell (m}^3\text{)} \times \% \text{Full} \times \text{Baffling Condition (T10/T)}]}{[\text{Maximum Day Flow (m}^3\text{/d)}] \times 1,440 \text{ min/d}}$$

Volume of Clearwell = 164 m3

% Full = 0.5

 $T_{10}/T =$

Actual Max. Day Flow 1,035 m3/d

Condition = Summer Time

T = 80 Minutes

Evaluation of Residual Chlorine Concentration (C):

C = CT for 2.5-log inactivation / T

CT = 66

C =	0.83 mg/L
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Off-Site Treatability Testing

Appendix C

MOEE/STB Treatability Data Report

Paisley

Objective Alum dose check

Date: 96/8/23 Sample Volume: 2 litre Run #: 1

Chemical Dosages (mg/L)

Jar	Coagulant type/dose	Alum 1%				
1	15					
2	25					
3	35					
4	45					
5	55					
6	65					

Observations

1	small non-sticky floc in all
2	50% on bottom after 20 standing
3	quite good at 50 minutes
4	
5	
6	

Chemical Analysis Data

Supernatant					Filtrate				
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Coag. Res.
1					0.48	17	8.2		
2					0.3	14	8		OR~300
3					0.25	11	7.9		OR~260
4					0.24	8	7.8		OR~200
5					0.27	9	7.6		OR~220
6					0.27	8	7.7		226
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

MOEE/STB Treatability Data Report

Paisley

Objective Check iron coagulant effectiveness

Date: 96/08/23

Sample Volume: 2 litre

Run #: 2

Chemical Dosages (mg/L)

Jar	Coagulant type/dose	Femclear 1%				
1	20					
2	30					
3	40					
4	50					
5	60					
6	70					

Observations 1 minute at 150 then 25 minutes at 20 rpm and standing

1	medium fine floc mostly down in 5 minutes - very good at 15 minutes
2	same
3	same
4	paddle skidding-10rpm best appearance
5	good
6	good

Chemical Analysis Data

Supernatant					Filtrate				
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity	Coag. Res.
1	1.08	28	7.25		0.71	19	7.4		OR
2	1.15	28	7.2		0.47	14	7.4		OR
3	0.91	25	7.2		0.39	11	7.3		OR
4	1.07	20	7.15		0.35	11	7.3		0.18
5	0.49	11	7.1		0.28	8	7.3		0.12
6	0.5	11	7.1		0.23	7	7.2		0.08
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

fair performance, better than alum alone but quite high dose needed

Objective Polymer + Alum effectiveness

Date: 96/08/22

Sample Volume: 2Litre

Run #: 3

Chemical Dosages (mg/L) 65 mg/L alum = 0.5 mg/L polymer

Jar	Coagulant type/dose				
1	LT 20				
2	LT 22				
3		8170			
4		8171			
5			LT24		
6				LT25	

Observations

1	Coarse floc forms in 1 minute, some floc settles very slow - suspended at 20 min
2	Very large flocs - settle well
3	Larger floc - again fast settling
4	Pin floc with poor settling
5	Large floc - completely clear on settling
6	Very large floc - a few particles remain suspended

Chemical Analysis Data

membrane ultrafilters data											
Supernatant							Filtrate				
	Turbidity	Colour	pH	Alkalinity	Turbidity	Colour	pH	Alkalinity			
1	0.55	8	7.4		0.42	8	7.4				181
2	0.55	8	7.4		0.29	7	7.4				166
3	0.52	8	7.4		0.24	6	7.4				170
4	1.03	10	7.4		0.29	7	7.4				158
5	0.61	3	7.4		0.23	6	7.4				162
6	0.48	8	7.4		0.32	7	7.4				161
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L			µg/L

Comments

Appearance good but residual Al too high

Objective Alum/ferriclar comparison

Date: 96/08/2?

Sample Volume: 2Litre

Run #:4

4

Chemical Dosages (mg/L)

Jar	Coagulant type/dose			
1	Alum 80 mg/L			
2	Alum 100 mg/L			
3	Alum 120 mg/L			
4	FCLR 80 mg/L			
5	FCLR 100 mg/L			
6	FCLR 120 mg/L			

Observations

1	All alum forms pin floc with no settling or clear zone at 20 minutes
2	
3	
4	All FCLR forms large floc, settles well -25% clear in 3 min all clear except fines traces at 7 min
5	
6	

Chemical Analysis Data

Supernatant	0.85	Colour	pH	Alkalinity	Filtrate	Colour	pH	TOC	Coag. Res.
1	0.85	11	7		Turbidity	7		4.3	OR~290
2	0.92	9	6.95		0.36	6			
3	1.19	10	6.87		0.52	6			
4	0.6	8	7.05		0.21	7		3.9	90
5	0.73	21	6.98		0.21	5			110
6	0.53	15	6.82		0.17	4			58
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	µg/L

Comments

Objective Aid effectiveness comparison using 65 mg alum or iron

Date: 96/08/27

Sample Volume:

2 litre

Run #: 5

Chemical Dosages (mg/L) aids at 0.2 mg/L

Jar	Coagulant type/dose				
Alum 1	LT22				
Alum 2	LT24				
Alum 3		8170			
FCLR 4			LT22		
FCLR 5			LT24		
FCLR 6					8170

Observations

1	Poor settling very fine floc
2	Largest, but still small and fastest settling floc
3	Second best size and settling of alums
4	Very fast, 5 min settling floc, clearest at 15 minutes of iron
5	Very fast, 5 min settling floc, non-sticky
6	Very fast - nearly same as 4 and 5

Chemical Analysis Data

Supernatant	Turbidity	Colour	pH	Alkalinity	Filtrate	Turbidity	Colour	pH	Alkalinity	Coag. Res.
1			7.25			0.29	6			146
2			7.25			0.2	5			140
3			7.25			0.24	6			130
4			7.18			0.21	8			40
5			7.18			0.32	9			100
6			7.18			0.21	6			50
	FTU	TCU	pH units	mg/L		FTU	TCU	pH units	mg/L	mg/L

Comments

MOEE/STB Treatability Data Report

Paisley

Objective Activated silica with main coagulants and FCLR/8170 comparison

Date: 96/08/28

Sample Volume: 2 Litre

Run #: 6

Chemical Dosages (mg/L)

Jar	Coagulant type/dose		
1	3.4 ml alum	1.06 ml act. silica	
2	6.5 ml alum	2.1 ml act. silica	
3	3.4 ml FCLR-2%	1 ml 8170	
4	6.5 ml FCLR-2%	2 ml 8170	
5	3.4 ml PACL	1 ml silica	
6	3.4 ml FCLR	1ml silica	

Observations

1	Large and medium floc in 6 to 7 minutes settles in 2 minutes standing, all down 15 min.
2	Larger floc , 6-7 minutes, settles in 2 minutes -all trace down in 15
3	finer floc fast formed 6-7 min, - still some suspended at 15 minutes
4	medium floc -still fast 6-7 minutes, still some suspended at 15 min standing
5	very big flocs in 3 minutes, completely settled in 3 min sedimentation
6	definitely slower floc formation - 10 min catching up

Chemical Analysis Data

Supernatant	Turbidity	Colour	pH	Alkalinity	Filtrate Turbidity	Colour	pH	Alkalinity	Coag. Res.
1					0.13	10	7.4		211 Al
2					0.16	8	7.25		80 Al
3					0.41	13	7.35		200 Fe
4					0.3	9	7.25		40 Fe
5					1.45	32			
6					0.14	9	7.87		~300 OR
	FTU	TCU	pH units	mg/L	FTU	TCU	pH units	mg/L	mg/L

Comments

Silica recipe supplied by plant - 1 gallon silica to 18 of water, add to 1.8 kg sodium bicarb dissolved in 8 gal water, mix, age for 2 hours then dilute to 41.6 gallons.

On-Site Testing

Appendix D

Paisley Water Plant - Analysis of Turbidity Data v. Alum Addition Location

day of month	Turbidity Regular	deviation	day of month	Turbidity Drum	deviation
10-Nov	0.16	-0.0791	12-Nov	0.24	0.0447
10	0.17	-0.0691	12	0.26	0.0647
11	0.32	0.0809	16	0.14	-0.0553
11	0.25	0.0109		0.15	-0.0453
14	0.42	0.1809	17	0.4	0.2047
14	0.23	-0.0091		0.13	-0.0653
15	0.21	-0.0291	20	0.18	-0.0353
15	0.14	-0.0991	21	0.13	-0.0853
18	0.33	0.0909	21	0.18	-0.0153
18	0.3	0.0609	22	0.12	-0.0753
19	0.77	0.5309	25	0.42	0.2247
19	0.28	0.0409	25	0.3	0.1047
20	0.17	-0.0691	28	0.15	-0.0453
22	0.16	-0.0791	26	0.12	-0.0753
23	0.14	-0.0991	27	0.17	-0.0253
23	0.13	-0.1091	29	0.14	-0.0553
24	0.11	-0.1291	30	0.2	0.0047
24	0.2	-0.0391	30	0.17	-0.0253
27	0.14	-0.0991	01-Dec	0.12	-0.0753
28	0.13	-0.1091	4	0.14	-0.0553
28	0.16	-0.0791	4	0.15	-0.0453
29	0.13	-0.1091	5	0.12	-0.0753
01-Dec	0.13	-0.1091	6	0.1	-0.0953
2	0.21	-0.0291	6	0.14	-0.0553
2	0.17	-0.0691	7	0.1	-0.0953
3	0.67	0.4309	7	0.11	-0.0853
3	0.2	-0.0391	8	0.12	-0.0753
4	0.38	0.1409	8	0.11	-0.0853
10	0.1	-0.1391	9	0.1	-0.0953
11	0.15	-0.0891	9	0.13	-0.0653
11	0.14	-0.0991	10	0.11	-0.0853
12	0.11	-0.1291	mean	0.1655	
12	0.13	-0.1091	s.d.	0.0803	
13	0.09	-0.1491			
mean	0.2215				
s.d.	0.1507				

Excluding two wild data points on 13 November data show regular addition turb .22 sigma .15
drum 0.16 sigma .08

Paisley Water Plant - Analysis of Turbidity Data v. Alum Addition Location

All data including excursions treated as logarithmic distribution

day of month	Turbidity Regular	100*T	log10 100T	day of month	Turbidity Drum	100T	log10 100T
10-Nov	0.16	16	1.20412	12-Nov	0.24	24	1.380211
10	0.17	17	1.230449	12	0.26	26	1.414973
11	0.32	32	1.50515	13	1.12	112	2.049218
11	0.25	25	1.39794	16	0.14	14	1.146128
13	0.84	84	1.924279		0.15	15	1.176091
14	0.42	42	1.623249	17	0.4	40	1.60206
14	0.23	23	1.361728		0.13	13	1.113943
15	0.21	21	1.322219	20	0.16	16	1.20412
15	0.14	14	1.146128	21	0.13	13	1.113943
18	0.33	33	1.518514	21	0.18	18	1.255273
18	0.3	30	1.477121	22	0.12	12	1.079181
19	0.77	77	1.888491	25	0.42	42	1.623249
19	0.28	28	1.447158	25	0.3	30	1.477121
20	0.17	17	1.230449	26	0.15	15	1.176091
22	0.16	16	1.20412	26	0.12	12	1.079181
23	0.14	14	1.146128	27	0.17	17	1.230449
23	0.13	13	1.113943	29	0.14	14	1.146128
24	0.11	11	1.041393	30	0.2	20	1.30103
24	0.2	20	1.30103	30	0.17	17	1.230449
27	0.14	14	1.146128	01-Dec	0.12	12	1.079181
28	0.13	13	1.113943	4	0.14	14	1.146128
28	0.16	16	1.20412	4	0.15	15	1.176091
29	0.13	13	1.113943	5	0.12	12	1.079181
01-Dec	0.13	13	1.113943	6	0.1	10	1
2	0.21	21	1.322219	6	0.14	14	1.146128
2	0.17	17	1.230449	7	0.1	10	1
3	0.67	67	1.828075	7	0.11	11	1.041393
3	0.2	20	1.30103	8	0.12	12	1.079181
4	0.38	38	1.579784	8	0.11	11	1.041393
10	0.1	10	1	9	0.1	10	1
11	0.15	15	1.176091	9	0.13	13	1.113943
11	0.14	14	1.146128	10	0.11	11	1.041393
12	0.11	11	1.041393				1.210714
12	0.13	13	1.113943				16.2
13	0.09	9	0.954243				0.162
	0.2391		1.299001				
	0.1816		19.49				
		logmean	0.1949				

NOV 10 → NOV 23

* RUNNING

Palsley Water Plant Logsheet

Date	Time	Turbidity in NTU			Sludge Blanket		Chlorine		Alum Feed
		With 2100P Raw	Process	Finished	With 1120C Process	Feet from top Meter	DR700 mg/L	Colour Whl	Source/role Regular Driem
11-10	8:45	16.9	1.94	.16	1.765	5.5	1.40	1.5	110
11-10	14:10	16.7	4.23	.17	3.781	5.5	1.66	1.7	110
11-11	8:35	9.2	3.14	.32	2.872	3.0	2.37	2.0+	110
11-11	21:00	7.92	4.73	.25	4.532	3.5	2.10	2.0+	100
11-12	8:35	7.66	3.41	.24	3.194	4.0	1.78	1.9	100
11-12	16:00	7.32	7.47	.26	6.910	3.0	2.44	2.0+	100
11-13	18:45	6.19	13.8	(1.12)	10.640	3.0	2.43	2.0+	100
11-13	16:00	4.80	7.99	.84	7.398	3.0	.88	1.7	106
11-14	11:00	4.52	4.09	.42	3.547	3.0	2.34	2.0+	100
11-14	19:00	5.53	3.72	.23	2.873	3.5	2.41	2.0+	120
11-15	10:00	6.70	4.18	.21	3.724	5.5	2.21	2.0+	120
11-15	16:00	6.69	4.16	.14	3.276	4.0	2.50	2.0+	120
11-16	9:00	3.68	4.60	.14	4.018	5.5	2.28	2.0+	120
11-16	17:00	4.01	4.71	.15	4.073	5.0	2.20	2.0	120
11-17	7:30	4.68	4.80	.40	4.104	5.0	2.24	2.0+	120
11-17	20:30	4.75	4.69	.13	4.183	5.5	1.98	2.0	120
11-18	9:30	6.69	6.69	.33	2.793	5.5	2.01	2.0+	120
11-18	16:45	16.70	16.90	.30	2.122	3.5	1.28	1.4	120
11-19	9:00	8.12	6.72	.77	5.493	5.5	1.73	1.8	120
11-19	16:45	8.09	4.47	.28	3.660	5.5	2.04	2.0	120
11-20	9:47	5.54	3.35	.17	2.814	6.0	1.96	2.0	120
11-20	20:30	3.94	3.40	.16	3.309	6.0	2.11	2.0	120
11-21	9:10	5.90	4.58	.13	4.012	6.0	2.05	1.8	120
11-21	19:30	4.29	2.41	.18	2.163	4.5	1.79	2.0	120
11-22	10:05	4.78	3.63	.12	3.747	5.0	2.14	2.0+	120
11-22	16:00	4.69	2.36	.16	1.764	6.0	1.83	1.8	120
11-23	8:55	3.77	4.67	.14	4.313	4.5	2.53	2.0+	120
" 23	10:00	3.65	4.42	.13	4.207	5.0	2.10	2.0	120

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* RUNNING

NOV 24 -> DEC 7

Palo Alto Water Plant Logsheet

Date	Time	Turbidity in NTU			Sludge Blanket		Chlorine		Alum Feed
		with 2100P	Process	Finished	with 1720C	Feet from top	DIR100	mg/L	Source/ratio
Mo/Day	Hour/min	Raw			Process	Hand		Colour	Regular
11-24	7:00	3.41	1.47	.11	1376	6.0	1.89	2.0	120
11-24	19:00	3.45	3.07	.20	2.803	6.0	1.94	2.0	120
11-25	7:45	3.38	2.31	.42	2.137	5.5	1.54	1.5	100
11-25	15:15	3.32	2.60	.30	2.272	5.5	1.92	1.8	100
11-26	10:35	2.74	3.26	.15	2.863	6.0	1.87	2.0	100
11-26	15:30	2.70	2.81	.12	2.435	6.0	1.74	1.8	100
11-27	9:00	2.88	3.75	.17	3.486	6.0	2.02	2.0	100
11-27	21:00	3.34	2.30	.14	2.226	5.5	1.45	1.5	116
11-28	10:05	2.58	3.68	.13	3.410	6.0	2.02	2.0	116
11-28	18:00	2.63	2.91	.16	2.802	6.0	1.94	2.0	116
11-29	8:30	2.49	2.36	.13	2.006	5.5	1.83	1.9	116
11-29	20:00	2.28	2.49	.14	2.147	6.0	1.97	2.0	115
11-30	8:30	2.65	2.41	.20	2.376	6.0	2.01	2.0	115
11-30	21:00	12.0	2.15	.17	2.173	4.5	1.52	1.7	115
12-01	8:45	17.1	5.48	.12	4.434	4.0	2.27	2.0	115
12-01	20:30	20.0	2.00	.13	1.773	5.5	2.33	2.0	118
12-02	9:40	9.94	4.28	.21	4.028	3.5	2.17	2.0	120
12-02	16:20	8.73	1.71	.17	1.738	5.5	1.76	1.8	120
12-03	7:20	6.39	3.35	.67	2.745	4.5	1.84	1.9	120
12-03	16:10	6.18	4.63	.20	4.414	5.5	1.82	1.7	120
12-04	9:30	7.78	3.02	.38	2.910	5.5	1.71	1.6	120
12-04	18:30	4.51	6.66	.14	5.938	3.0	2.27	2.0	120
12-05	9:40	7.67	8.01	.15	6.394	3.5	1.94	1.9	120
12-05	22:00	3.86	5.55	.12	1.505	3.5	2.01	2.0	120
12-06	9:05	4.06	4.30	.10	3.629	6.0	1.88	1.8	120
12-06	17:00	3.72	4.35	.14	3.173	6.0	1.15	1.8	120
12-07	9:00	3.66	1.62	.10	.883	6.0	1.62	1.6	120
12-07	11:00	3.29	3.57	.11	3.267	5.0	1.96	1.9	115

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Dec 8. - Dec 13

Date	Time 24 hour Hour/min.	Turbidity in NTU			Sludge Blanket		Chlorine		Alum Feed	
		with 210DP Raw	Process	Finished	with 1720C Process	Feet from top Hand Meter	DR700 mg/L	Colour/WHI	Regular	Drum
12-08	9:00	3.38	6.40	.12	5.538	6.0	1.88	1.8		120
12-08	17:35	3.29	4.27	.11	5.129	6.0	1.79	1.8		120
12-09	10:30	5.40	5.82	.10	5.381	6.0	2.03	2.0		120
12-09	15:45	4.44	5.29	.13	4.385	6.0	2.14	2.0		120
12-10	10:30	2.67	3.17	.11	2.369	6.0	1.53	1.4		120
12-10	15:30	3.75	4.12	.10	3.600	6.0	1.89	2.0	120	
12-11	7:45	2.69	1.40	.15	1.314	6.0	1.91	1.8	120	
12-11	15:40	4.76	1.80	.14	1.686	5.5	1.80	1.8	120	
12-12	7:20	3.29	1.76	.11	1.349	5.5	1.99	2.0	120	
12-12	15:40	4.41	5.20	.13	3.906	6.0	2.22	2.0	120	
12-13	7:45	5.43	14.90	.09	4.892	5.5	2.01	2.0	120	

Certificate of Approval

Appendix E

Whereas / Attendu que VILLAGE OF PAISLEY

and

has applied in accordance with Section 23 of the Ontario Water Resources Act for approval of:
 a fait, conformément à l'article 23 de la loi sur les ressources en eau de l'Ontario, une demande d'autorisation:

improvements to the Water Treatment Plant serving the Village of Paisley consisting of modifications to the existing chlorination facilities and installation of a 19960 litre alum storage tank together with chemical feed pumps, internal piping, valves, control system and associated appurtenances, all in accordance with the plans and specifications prepared by Gamsby and Mannerow Limited, Consulting Engineers, at a total estimated cost, including engineering and contingencies, of THIRTY FOUR THOUSAND F HUNDRED DOLLARS (\$34,400.00).

THIS IS A TRUE COPY OF THE
 ORIGINAL AS SAME HANDED
 TO THE

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 23 of the Ontario Water Resources Act.
 Le présent document certifie qu'après vérification en bonne et due forme la construction dudit projet d'ouvrages a été approuvée aux termes de l'article 23 de la loi sur les ressources en eau de l'Ontario.

DATED AT TORONTO this 23th day of August, 1983

DATE À TORONTO ce 23 jour de
 Attesté: -Mr. R. Brown, Clerk, Village of Paisley
 cc: -Mr. L. De Vries, Village Engr.
 -Mr. D. A. McTavish, Dir. SW Reg., MCE
 -Gamsby and Mannerow Ltd.



Environment

Certificate of Approval (Water)

Whereas VILLAGE OF PAISLEY

XX

has applied in accordance with Section 41 of The Ontario Water Resources Act for approval of:-

Modifications to the existing water treatment plant in the Village of Paisley consisting of the construction of a raw water intake to be located at the bank of the Teeswater River complete with concrete inlet structure, removable screen, and approximately 90 ft. long intake pipe from the inlet structure to the Treatment Building, all in accordance with the plans and specifications prepared by Gamsby and Mannerow Limited, Consulting Engineers, at a total estimated cost, including engineering and contingencies, of ELEVEN THOUSAND FIVE HUNDRED DOLLARS (\$11,500.00).

THIS IS A TRUE COPY OF THE
ORIGINAL CERTIFICATE MAILED

ON Aug 25/8
CS
(SIGNED)

Now therefore this is to certify that after due enquiry the said proposed works have been approved under Section 41 of The Ontario Water Resources Act. (R.S.O. 1970)

DATED AT TORONTO this

17th

day of

August

1981

Attn: Mr. R. Brown, Clerk, Village of Paisley

cc: Mr. L. de Vries, Village Engineer

Mr. D.A. McTavish, MOE SW, Reg. Dir. ✓

Gamsby & Mannerow Limited



MINISTRY OF THE ENVIRONMENT

WATER WORKS APPROVAL

cc W. Page

Whereas

VILLAGE OF PAISLEY

has

has applied in accordance with Section 11 of The Ontario Water Resources Act for approval of:

subject to the submission and subsequent approval of satisfactory final plans and specifications, installation of two (2) 250 I.G.P.M.

water pumps in the existing pumphouse in the Village of Paisley

Water Works, and modifications to piping, valves and other auxiliary equipment as required; in accordance with the preliminary plans and calculations submitted by Gamsby and Mannerow Ltd., Consulting Engineers, at a total estimated cost, including engineering and contingencies, of TWENTY TWO THOUSAND DOLLARS (\$22,000.00).

THOMAS J. ... JUN 10 1977

Now Therefore

Section 11 of The Ontario Water Resources Act

DATED AT TORONTO

8th

day of

June

1977

c.c. L. DeVries, Road Superintendent
Gamsby and Mannerow Limited
405 Regional Division, 2nd Floor

MINISTRY OF THE ENVIRONMENT,

WATER WORKS APPROVAL

Whereas..... THE MUNICIPAL CORPORATION

of.....VILLAGE OF PAISLEY

has submitted to the Executive Director, Water Supply and Pollution Control, of the Ministry, plans, specifications and an engineer's report of the proposed works hereinafter referred to, together with such information as the Executive Director has required and has applied for approval of:-

construction of an extension to the water treatment plant to provide a total treatment capacity of 0.36 MGD, including the construction of a new treatment building together with the installation of one 18.5 ft. dia. solids contact clarifier, two 10 ft. dia. pressure filters, backwash pump, one 250 gpm high lift pump, one 250 gpm low lift pump, raw and treated water piping, flow meter, hypochlorination system, chemical feed system, electrical controls and all appurtenances, all in accordance with the plans prepared by Gamsby and Mannerow Limited, Consulting Engineers, at a total estimated cost, including engineering and contingencies, of SIXTY THREE THOUSAND DOLLARS (\$63,000.00),

Now Therefore this is to certify that the Executive Director after due enquiry has approved the said proposed works under Section 41 of The Ontario Water Resources Act.

DATED AT TORONTO this.....11th..... day of..... October 1972

R. H. Sharpe
Executive Director

Analytica! Procedures used by Novamann

Detection Limit and Analytical Method Reference used by Novamann

PARAMETERS	MINIMUM DETECTION LIMIT(MDL)	ANALYTICAL METHOD	METHOD REFERENCE*
THM	6 µg/L	Purge & Trap GC/MS	EPA 624
TOC	0.1 mg/L	UV/PEROX/FID	EPA 9060
residual aluminum	0.025 mg/L	ICP	EPA 6010
turbidity	0.1 NTU	Turbidity Meter	APHA 2130
true colour	1 TCU	Colourimetric	APHA 2120
pH	0.01	pH Meter	APHA 4500H
alkalinity	1 mg/L - CaCO ₃	Titration	APHA 2320
ammonia + ammonium	0.05 mg/L	Colourimetric	APHA 4500
anions (NO ₃ , Cl, SO ₄ , F)	0.1 to 0.5 mg/L	Ion Chromatography	EPA 300.0
conductivity	1 umho	Conductivity Meter	APHA 2510
lead	0.002 mg/L	Graphite Furnace	EPA 7421
metals		ICP	EPA 6010
nitrite	0.1 mg/L	Colourimetric	APHA 4500
orthophosphate-P	0.005 mg/L	Colourimetric	APHA 4500

Note * : EPA : Environmental Protection Agency
 APHA : American Public Health Association

